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Pacific Whiting and Myxosporidia

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On the cover: Transmission electron micrograph of a myxosporidian, *Kudoa* spp., which infects Pacific whiting (19,000 ×). See the article beginning on page 1. Micrograph contributed by Joyce Hawkes, Environmental Conservation Division, NMFS Northwest and Alaska Fisheries Center, Seattle, Wash.

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Pacific Whiting, *Merluccius productus:* I. Abnormal Muscle Texture Caused by Myxosporidian-Induced Proteolysis

MAX PATASHNIK, HERMAN S. GRONINGER, Jr., HAROLD BARNETT, GEORGE KUDO, and BARBARA KOURY

ABSTRACT—Pacific whiting, Merluccius productus, *has not been widely exploited by the U.S. fishing industry as a food fish because of its variable and often overly soft texture when cooked. During the past 15 years, studies were made to determine the cause of the abnormal texture and to investigate processing techniques and/or product forms that would make it possible to market whiting products having a relatively normal texture. The following conclusions result from these studies: The abnormal muscle texture in Pacific whiting is caused by a myxosporidian-induced proteolysis. The latent potential for proteolytic textural softening in whiting, due to the presence of myxosporidian cysts of variable intensity, appears to be an intrinsic characteristic of the Pacific species. The enzyme appears to be highly localized within the cyst and has little effect on the muscle fibers if the fish are promptly chilled upon catching, maintained chilled during processing, and rapidly cooked. It has been recommended that Pacific whiting be marketed as a fast-cooked or deep-fat-fried, portion-type product, limited to about 3/8 inch in thickness.*

Introduction

Despite the vast abundance of Pacific whiting, *Merluccius productus,* off the west coast of the United States, it has been little exploited by the U.S. industry because it has been considered unsuitable as a food fish due to its variable and often overly soft texture when cooked. Initial work with whiting during the middle-1960's related the visual presence of hairlike cysts containing myxosporidian spores and the accompanying high level of proteolytic activity in the infected flesh with its abnormal, soft texture. This was similar to the condition that was previously reported in Pacific coast species of milky halibut, sole, flounder, and salmon (Patashnik and Groninger, 1964) and to that reported in Mauretanean hake (Fletcher et al., 1951) and in Australian barracouta (Willis, 1949).

Willis described the various developmental stages of the myxosporidian chloromyxum thyrsites after the death of the host fish. He hypothesized that the parasite releases a powerful extracellular enzyme that is removed in the blood stream while the host fish is alive. After the fish dies and the circulation ceases, the enzyme progressively diffuses outward from the infected focus (the cyst) to the noninfected flesh.

The class Myxosporidia[1] is the most numerous group of protozoan parasites in fishes, with almost 300 reported species (Lom, 1970). The protozoan invasion of fish is far more dependent on ecological conditions (type and amount of food, temperature, stress conditions, etc.) than is true of terrestrial animals. These conditions interact with the fine balance between the protective mechanism of fish and the virulence of the protozoa (Lom, 1970). Since man has little control over the infection in nature, the condition must be accepted as an intrinsic property of the fish species.

This type of parasitization occurs in both cold- and warmblooded animals. For example, a similar type of protozoan parasite is found in the skeletal muscle fibers (sarcocysts with masses of spores) in all classes of livestock and may be found in as many as two-thirds of healthy beef carcasses of different grades (American Meat Institute Foundation, 1960). This muscle parasite is of little concern since it does not affect the texture of the meat when cooked and does not affect man otherwise.

The muscle parasite that affects whiting similarly is of little public health concern, but since it degrades flesh texture significantly and limits the utilization of the resource, it is a matter of technological concern. This emphasized the need to broaden our understanding of the parasite and of the related texture problem. As the extent of the problem became clearer, studies on how to control or minimize adverse effects on flesh texture during harvesting and processing of the whiting became increasingly important.

Research on the texture problem in whiting during the middle 1960's and early 1970's was limited due to the absence of industry interest in marketing this species. In recent years the enactment of the 200-mile fishery conservation zone legislation and the need to

[1]Changed to Myxosporea by Levine et al. (1980).

Max Patashnik, Chemical Engineer; Herman S. Groninger, Jr., Research Chemist; Harold Barnett, Research Chemist; George Kudo, Chemist; and Barbara Koury, Research Chemist, are with the Utilization Research Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, WA 98112.

complement declining traditional fishery resources have awakened industry interest in the use of Pacific whiting for fresh and frozen products and have activated our research efforts.

This paper summarizes our early and more recent research on 1) the nature and extent of the abnormal texture problem and 2) the evaluation of various processing treatments to minimize the problem. Two additional papers are scheduled: 1) the commercial processing procedures necessary for producing a texturally acceptable, domestic frozen product, and 2) the potential utilization of Pacific whiting in the United States and/or Japan for a kamaboko-type fabricated product based on its elastic properties.

Materials and Methods

Fish Samples

During the past 15 years, numerous Pacific whiting samples were obtained from various sources off the Washington and Oregon coasts and, to a lesser extent, off the California coast. The early 1964-65 and many later whiting samples were caught by the NMFS RV *John N. Cobb.* Samples were obtained and examined from charter research vessels, commercial fishing vessels, and Soviet factory ships. During the years 1976-79, sampling and on-board research were carried out aboard the commercial trawler MV *Willapa Bay,* the Polish RV *Profesor Siedlecki,* and the chartered trawlers RV *Forerunner* and MV *Kupreanof.*

Sample lots examined consisted of freshly landed whiting aboard vessel; uniced, iced, and refrigerated seawater-held whiting delivered to commercial fish-processing plants; whiting immediately frozen aboard vessel and later in shore processing plants; whiting variously treated aboard vessel prior to freezing; live whiting frozen in dry ice aboard vessel; and whiting processed and frozen into fillet blocks aboard vessel. The whiting were examined in the round, as frozen and thawed fillet block portions, and as raw and slow- or fast-cooked portions and fillets. The samples were examined with particular reference to the nature of the abnormal texture problem and the severity and incidence of the parasite in the whiting population.

Texture Evaluation

The slow-oven-cooked (oven temperature 400°F) and the fast-cooked, battered-and-breaded, deep-fat-fried (fat at 385°F) samples were examined separately by three project personnel experienced with whiting texture, using the fish flesh only for evaluation. A 5-point rating scale was used for texture as follows: 5 = firm to normal; 4 = normal to soft; 3 = soft; 2 = overly soft; 1 = mushy, pasty. Categories 1 and 2 were considered unacceptable.

Severity and Incidence of Parasitization

The severity of parasitization was estimated by visual observation of parasitic cysts in a section or fillet of the raw fish. The rating scale for cyst intensity was based on the percent area of the fillet affected and density was as follows: 0 = none (0 percent); 1 = trace (up to 5 percent); 2 = slight (5-20 percent); 3 = moderate (20-30 percent); 4 = severe (30-50 percent); 5 = excessive (>50 percent).

Categories 3, 4, and 5 were considered "grossly parasitized" and readily cullable at processing plants from a moving conveyor belt with good lighting. Categories 1 and 2 required careful examination and were not readily cullable. Any fish with observable cysts, from trace to excessive, was considered positive in estimating the incidence of parasitization in whiting population samples. Inevitably, some fish with low-level cyst density are missed; therefore such estimates are on the low side. Data on percentage of fish affected in various samples are measures of the incidence of parasitization; data on the cyst density in an individual fish are measures of the severity of parasitization.

Chemical Determinations

Proteolytic enzyme determinations were made on samples frozen at sea using the method described in Patashnik and Groninger (1964). Whiting muscle was homogenized for 2 minutes in cold water 1:3 (weight:volume) and the homogenate was centrifuged at approximately 17,000 G. The supernatant was used for the enzyme determinations. The pH of muscle and muscle preparations were determined with a glass electrode.

Employing Dyer's protein method (Dyer et al., 1950), flesh samples (below dorsal fin) were extracted in 0.85 M sodium chloride and 0.003 M sodium bicarbonate and centrifuged at 760 G. Total soluble nitrogen and myofibrillar protein nitrogen were determined on an aliquot of the supernatant. Nonprotein nitrogen was determined on the supernatant of another aliquot after precipitation of the protein with 5 percent trichloroacetic acid. All protein and nonprotein determinations were done by the micro-Kjeldahl method of Minari and Zilversmit (1963). Total soluble protein and sarcoplasmic protein were determined by difference.

Proximate composition determinations were made using the standard procedures of the A.O.A.C. (1980).

Microscopy

For microscopic examination, a few muscle fibers from two or three areas of the raw and/or cooked flesh were teased out and placed in one or two drops of water on a glass microslide and covered with a cover glass. The condition of the muscle fibers and the presence of cysts and myxosporidian spores were observed under 450× magnification.

For histology, samples of fresh or frozen material were fixed in Bouin's solution, imbedded in paraffin, and sectioned at a thickness of 6μm. Sections were stained with May-Grunwald Giemsa stain to bring out the polar capsules. Dark staining bodies appearing in some slides were decolorized for 5 minutes with 1 percent acetic acid in order to reveal their relationship to the other spore tetrads present.

In addition, portions of fish tissue from fresh fish were obtained for further light and electron microscopic studies. Some of the tissues were sampled immediately after capturing the fish and others were from fish that had been incubated at 16°C for 0.5, 7, 31, and 48 hours. Cubes of tissue 0.5 × 0.5 × 0.5 cm were initially fixed in a solution containing 0.75 percent glutaraldehyde, 3 percent Formalin, 0.5 percent acrolein, and 0.1 M sodium

cacodylate buffer (pH 7.4) with 0.02 percent $CaCl_2 \cdot H_2O$ and 0.5 percent sucrose (Hawkes, 1974). The cubes were cut into smaller portions, 1.0 mm on each side, washed in buffer (0.1 M sodium cacodylate, 0.02 percent $CaCl_2 \cdot H_2O$, 5.5 percent sucrose), and post-fixed in 1 percent osmium tetroxide in buffer. Dehydration with ethanol and embedding in plastic (Spurr, 1969) completed the preparation of the tissue for sectioning with either glass or diamond knives. Semithin (1.0 μm) sections were prepared with Richardson's stain for light microscopy. Thin sections were triple stained with lead citrate, uranyl acetate, and again lead citrate for electron microscopy.

Results and Discussion

Incidence and Severity of Parasitization

Early in our investigation (May-October 1964-66), using the RV *John N. Cobb*, we extensively sampled the Pacific whiting population of the coastal areas off the Washington-Oregon coast for incidence and severity of myxosporidian infection. Overall, we found an incidence of 20-40 percent of the fish in the samples (10-50 fish per sample) to be infected with visually apparent "hairlike" cysts at the 5-100 percent level. Over three-fourths of the samples had individual fish with a severity of 20 percent cyst density or higher. About 8 percent of the parasitized fish were considered to be "grossly parasitized" and were readily cullable; the balance were uninfected or trace to slightly infected and not readily cullable. In other words, 2-3 percent of the whiting population were grossly parasitized and could be culled by sorting if necessary. Two samples of juveniles (34 g size) among the 38 lots of fish examined during this period were found to be unparasitized, suggesting that the infection may be acquired beyond the juvenile stage.

It was hoped that with the heavy fishing of the resource by foreign fleets since 1966 the incidence of parasitization would be substantially reduced. Nevertheless, periodic sampling during 1967-75 and the heavier sampling during 1976-79 indicated only a slight but insignificant downward trend. In recent years, the percentage of grossly parasitized (cullable) whiting appears to have decreased to the 4-5 percent level of the infected fish, i.e., about 1 percent of the whiting harvested. The visual incidence and severity (cyst density) of parasitization between fish and within fish varies widely from catch to catch and does not seem to be associated with area, depth, or season.

It appears then for developing a fishery one must expect that a relatively small but significant part of the Pacific whiting resource is intrinsically affected with myxosporidian cysts of variable intensity and distribution. This is associated with a relatively higher than normal level of proteolytic activity in the affected flesh areas of the fish, which may adversely affect the texture of both the raw and cooked product. To minimize this texture problem, it was clear that we needed to better understand the relationship between 1) the parasite and the fish muscle, and 2) the related effect of the proteolytic enzyme in the flesh and the time-temperature handling history of the whiting.

Parasitized Condition Involves Enzyme-Induced Proteolysis

Initially it was important to determine whether the texture problem in parasitized whiting was, in fact, proteolytic in nature. The data in Table 1 (variously treated lingcod gels) demonstrated that the parasitized condition in whiting was associated with an enzyme-induced proteolysis. Compared to the lingcod control, the control with added visually normal whiting showed a 30 percent greater proteolytic activity, which indicated a higher proteolytic activity even in normal-appearing whiting.

In contrast, the control with added grossly parasitized whiting showed a 700 percent greater proteolytic activity. However, the control with the parasitized whiting with added mercuric nitrate (enzyme inhibitor) showed a 50 percent lower proteolytic activity than the lingcod control and demonstrated that the enzymic activity of both the lingcod and the grossly parasitized whiting was largely inactivated.

Six control or normal whiting with no visual parasitization were compared with six cyst-infected, parasitized whiting for relative proteolytic activity. Results in Table 2 show a sevenfold higher average proteolytic activity in the parasitized group than the normal-appearing group

Table 1.—Comparison of the degree of protein breakdown of lingcod control gels[1] treated with normal and grossly parasitized Pacific whiting with and without an enzyme inhibitor after incubation at 100°F for 20 hours (whiting obtained by the RV *John N. Cobb* off the Washington coast, October 1967).

Treatment	Relative optical density[2] (degree of protein breakdown)
Lingcod control	1.0
Lingcod + 30 percent normal whiting	1.3
Lingcod + 30 percent grossly parasitized whiting	7.0
Replicates	
Lingcod + 30 percent grossly parasitized whiting	7.4
Lingcod + 30 percent grossly parasitized whiting + 0.1 percent mercuric nitrate (enzyme inhibitor)	0.5

[1]Homogenized fish gels made with 5 percent NaCl solution (1:2 by weight) using lingcod as control substrate.
[2]Optical density was determined at 280 nm on TCA extracts to estimate the relative degree of protein breakdown. The relative optical density was expressed as the ratio of the optical density of the treatments over that of the lingcod control.

Table 2.—Comparison of proteolytic activity in normal and myxosporidian (*Kudoa* sp.) infected Pacific whiting (whiting obtained by the RV *John N. Cobb* off the Washington coast, October 1965).

Group	Parasite[1] cyst intensity	Steam-cooked flesh condition	Proteolytic[2] activity
Normal control	0	Normal and flaking	0.5
"	0	"	0.8
"	0	"	0.9
"	0	"	0.6
"	0	"	0.8
"	0	"	0.4
		Average	0.67
Parasitized	5	Pasty	6.1
"	5	"	[3]1.4
"	1	"	5.3
"	3	"	3.7
"	3	"	5.0
"	4	"	5.7
		Average	4.53

[1]Parasite cyst intensity or density based on visual appearance scale of 0 = none; 1 = trace; 2 = slight; 3 = moderate; 4 = severe; and 5 = excessive.
[2]Activity was determined at pH = 3 using hemoglobin as substrate (g of tyrosine liberated $\times 10^3$ per 100 mg per 30 minutes).
[3]This sample had lysed pockets and an abnormal low pH = 6.14. (Proteolytic activity may have been dissipated.)

of samples. The level of proteolytic activity within the parasitized groups did not correlate directly with the visually estimated degree of parasite cyst intensity. The increased proteolytic activity of the parasitized whiting ranged from 2 to 15 times greater than the controls. In subsequent comparisons, we found parasitized whiting with proteolytic activities up to 30 times greater than that in the control.

Relation of Parasitization to Flesh pH

In several experiments where parasite-infected fillets were held at 32-34°F for periods of up to several days, we occasionally found enzyme-liquefied pockets on the fillet surface and interior, similar to the occurrence noted in halibut or salmon (Patashnik and Groninger, 1964). The pH of the lysed pockets in halibut and whiting have consistently been measured at 6.1-6.4, which is lower than the pH in other areas on the fillet. The lysed pockets have been found usually in whiting with a lower muscle pH. The average pH of parasitized whiting is usually observed to be slightly lower than that in normal whiting as shown in Table 3 (6.48 vs. 6.67). The lower pH of parasitized whiting may explain the poorer water-holding capacity of the cooked protein of seriously parasitized whiting. This is similar to the poor water-holding capacity found in low pH halibut (Patashnik, 1966).

Relation of Parasitization to Level of Flesh Protein

In utilizing Pacific whiting as a food fish, the level of available protein is important. If the parasite has an adverse effect on the host fish, we might anticipate the myofibrillar proteins to decrease and the sarcoplasmic proteins to increase. The protein content of six visually normal whiting are compared in Table 3 with six significantly parasitized whiting from the same catch. The data show that the myofibrillar protein content of the parasitized group decreased by 11 percent (16.2 vs. 14.4) and the sarcoplasmic protein increased by 15 percent (6.0 vs. 6.9). The total soluble protein nitrogen for the parasitized whiting, however, decreased by only 3 percent (22.2 vs. 21.5), an insignificant change.

Table 3.—Comparison of protein and nonprotein nitrogen and pH in normal and myxosporidian (*Kudoa* sp.) infected Pacific whiting (whiting obtained by the RV *John N. Cobb* off the Washington coast, October 1965).

Group	Parasite[1] cyst intensity	Total soluble nitrogen	Total soluble protein	Myofibrillar	Sarcoplasmic	NPN	pH
				mg N/g			
Normal	0	27.8	24.0	16.3	7.7	3.8	6.56
"	0	27.0	23.0	17.7	5.3	4.0	6.63
"	0	26.0	22.3	17.4	4.9	3.7	6.65
"	0	25.6	21.6	17.7	3.9	4.0	6.56
"	0	28.6	24.7	17.1	7.6	3.9	6.75
"	0	20.0	17.5	11.2	6.3	2.5	6.84
Average		25.8	22.2	16.2	6.0	3.7	6.67
Parasitized	5	23.8	21.5	13.9	6.6	3.3	6.64
"	3	24.0	20.8	16.0	4.8	3.2	6.62
"	5	26.0	22.2	13.6	8.6	3.8	6.14
"	4	24.0	19.6	15.5	4.1	4.4	6.32
"	3	27.6	23.6	14.2	9.4	3.8	6.45
"	1	24.8	21.0	13.1	7.9	3.8	6.73
Average		25.0	21.5	14.4	6.9	3.7	6.48

[1]Parasite cyst intensity or density based on visual appearance scale of 0 = none; 1 = trace; 2 = slight; 3 = moderate; 4 = severe; and 5 = excessive.

In Table 4, an excessively parasitized whiting (raw fillet flesh pasty and full of enzyme-liquefied pockets) was compared with a group of seven slightly to moderately parasitized whiting. The abnormally high moisture, low protein, and low ash for the excessively parasitized whiting indicate a significant adverse effect on its chemical composition. This fish would ordinarily have been culled during processing. Since the protein-water relationships of the slightly to moderately parasitized whiting in Table 4 are well within the normal range, this would indicate a minimal nutritional effect on the host-parasite relationship for most affected whiting.

Table 4.—Comparison of the proximate composition of all excessively parasitized Pacific whiting with seven slightly-to-moderately parasitized whiting.

Degree of parasitization	Moisture (%)	Protein (%)	Oil (%)	Ash (%)
Slightly and moderately parasitized	83.4	15.5	0.29	1.05
Very excessively parasitized	87.0	11.1	0.36	0.72

Inactivation of the Enzyme by Heat

Since the texture of whiting muscle is greatly affected by the parasite-induced proteolysis during cooking, the stability of the enzyme(s) toward heat is of great importance. The heat inactivation of the enzyme(s) at various temperatures is shown in Table 5. The enzyme(s) was completely inactivated by heating at 70°C (158°F) for 10 minutes. This suggested that we must rapidly achieve an internal temperature of 160°F or higher to inactivate the enzyme during cooking.

Various methods of rapid heating to inactivate the enzyme before flesh proteolysis ensued were thus examined. In studies on microwave cooking of fillets, it was determined that parasitized 3-day-iced fillets (frozen and thawed for cooking) were normal in texture when rapidly microwave-cooked to a center-of-fillet temperature of 160°F within 1.5 minutes. In other studies on accelerated

Table 5.—Heat inactivation of proteolytic activity of parasitized Pacific whiting muscle extracts.

Temp. °C	Temp. °F	Activity remaining[1] (%)	Temp. °C	Temp. °F	Activity remaining[1] (%)
2	35.6	100	60	140.0	42
50	122.0	76	65	149.0	10
55	131.0	74	70	158.0	0

[1]Extract was heated for 10 minutes at pH = 6.7. Proteolytic activity was determined at pH = 3 using hemoglobin as a substrate.

heating, it was determined that deep-fat frying at 385°F of battered-and-breaded, 3/8-inch-thick cut sections of parasitized whiting produced similar normal textures. To achieve rapid heat inactivation of the enzyme(s) during cooking, the deep-fat-frying method was found to be the more effective and practical approach. This method will be discussed in greater detail in part II of this series of papers.

Severity of Parasitization and Relation to Abnormal Texture

Three criteria were used for estimating the severity of parasitization: 1) the visual presence of dark or white hairlike cysts, 2) microscopic examination of muscle for typical myxosporidian spores, and 3) sensory detection of abnormally soft or mushy texture of samples prepared by slow oven cooking.

The visual presence of parasitic cysts in a fillet (Fig. 1) provides an estimate of the severity of parasitization in a fish, but this figure may not correlate with the degree of proteolytic softening in the cooked product, as not all the visually parasitized fish develop an abnormal texture on cooking. Microscopic examination more accurately reflects the severity and developmental stage of parasitization in a sample; it is usually the best indicator of the likely predisposition to abnormal texture on cooking. Sensory evaluation of the slowly cooked flesh determines the actual portion of the parasitized fish samples that are sufficiently parasitized to become overly soft or mushy. Occasionally, a severely parasitized fish (all black cysts) will have a normal, chewable cooked texture, whereas a normal-appearing fish (visually free of parasitic cysts) but one which contains a significant quantity of microscopically identifiable cysts or low-contrast white cysts will become mushy on cooking.

On microscopic examination, we have commonly found samples of Pacific whiting to be 90-100 percent parasitized in varying degrees from trace to severe. When these lots were examined visually — the criteria most commonly used because of its speed — the incidence of parasitization was found to be much lower. We have found the severity of parasitization with white cysts (visual or subvisual) to be the best indicator of the predisposition to abnormal cooked texture. This was statistically confirmed ($P<0.001$) in our collaborative work with Polish research scientists aboard the RV *Profesor Siedlecki* in August 1977 (Schwartz et al., 1978).

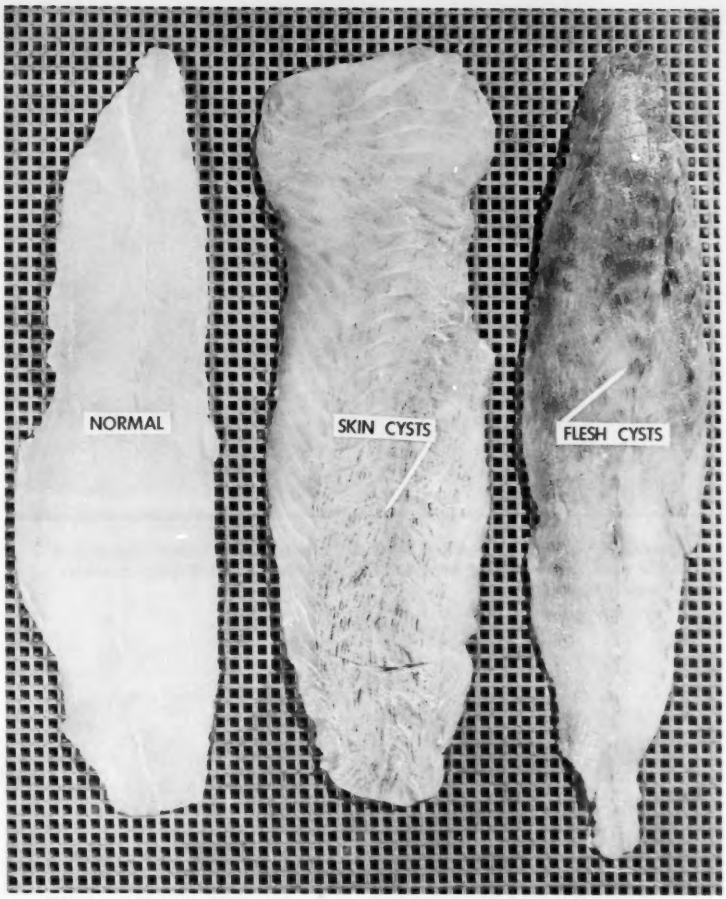

Figure 1.—A normal Pacific whiting fillet in contrast with heavily parasitized whiting fillets showing hairlike white and black cysts.

Macroscopic and Microscopic Appearance of Parasite

Macroscopically, the cysts appear as dark and/or white filaments between myotomes (Fig. 1) and may be closely packed or widely separated depending on the severity of the infection. The cysts may be either uniformly or unevenly distributed through the interior flesh, on the flesh surface below the skin, or clustered in localized areas only (Fig. 2). The nape end of the fish fillet is usually found to be more heavily parasitized than the tail (Fig. 1).

Microscopically, in wet mounts, the cyst is commonly seen within the muscle fiber and is packed with a myriad of myxosporidian spores. In the thousands of samples examined, we have observed

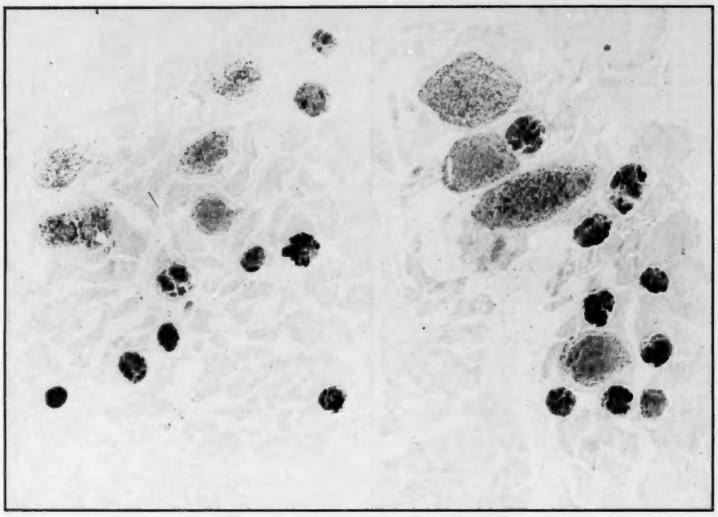

Figure 2.—A histological section through the muscle of a heavily parasitized Pacific whiting showing the distribution of various size and shape cysts within the muscle fiber (16×).

cysts ranging from subvisual size both in diameter and in length along the muscle fiber to those occupying the entire muscle fiber (Fig. 3).

The black or darker cysts are the older, more mature ones and are colored with a light- to dark-brown pigment. As the cyst ages, the granular, brownish pigmented material, which was initially localized (Fig. 4), spreads throughout the cyst. Very old cysts are pigmented throughout, devoid of spores, and no longer proteolytically active. This explains why some fillets with dark cysts may have low proteolytic activity and be normal in texture. Other dark cysts may still retain part or much of their proteolytic activity and be abnormal in texture to varying degrees.

The white cyst is the younger and more proteolytically active form and the main source of texture problems. Being white and in poor color contrast with the surrounding flesh, it is less readily

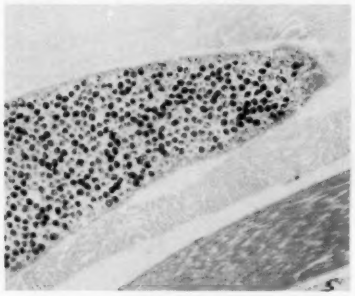

Figure 3.—A histological section through an infected muscle fiber showing an elongated cyst packed with myxosporidian spores (190×).

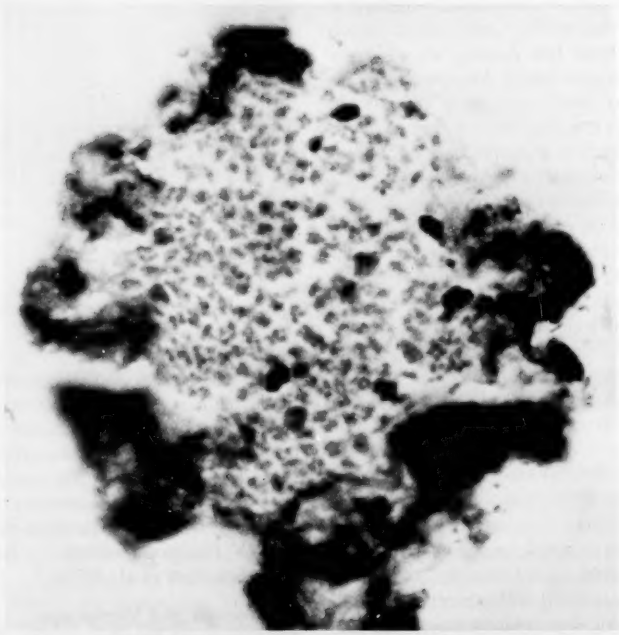

Figure 4.—A histological section through an individual cyst showing numerous myxosporidian spores within and the deposition of dark pigmented material on the periphery (300×).

apparent on visual inspection; thus such fillets are more difficult to cull than those containing black cysts. The microscopic cysts are usually found to be young, active, and growing.

Since it is impractical to cull whiting fillets containing either white-colored or microscopic cysts, they may be present in most processed whiting. This is essentially the nature of the texture problem in whiting and the basis for our research on control through handling and processing. The problem will have to be controlled by time-temperature handling by the catcher vessel, processor, and consumer to minimize the enzymatic activities that result in the adverse texture in the cooked product. Inspection and elimination of fillets with readily apparent cysts should be done largely for esthetic reasons and to eliminate severely parasitized, potential problem fish.

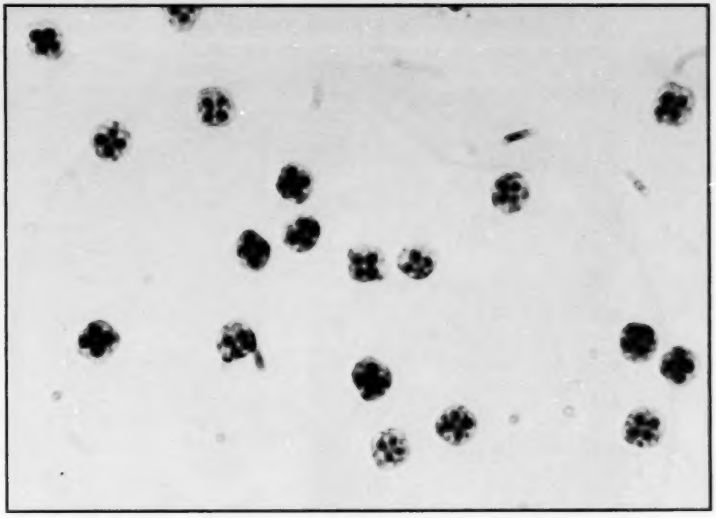

Figure 5.—The small myxosporidian spore in Pacific whiting (*Kudoa* sp.) as seen in aqueous wet mount made from cooked or raw flesh (700×).

Morphology and Structure of Myxosporidia

The classification and identification of the myxosporidia are based almost entirely upon the structure of the spore. The myxosporidian spore in whiting (*Kudoa* sp.) is best seen in an aqueous wet mount containing a small quantity of flesh fibers teased from either cooked or raw flesh and viewed at 450× or 1,000× magnification. Samples of mushy cooked flesh invariably show copious quantities of typical spores. The typical spore commonly seen associated with Pacific whiting is a small 4-6 μm spore containing four oval-shaped polar capsules. Microscopically, it appears as a square with rounded corners for four equally sized ovoid capsules (Fig. 5). About 30 percent of the whiting samples may display a coinfection with a large myxosporidian spore 8-18 μm in size containing 4 subequal-sized elongated capsules encapsulated in a starlike 4-pointed sheath. Histological sections of the two types of myxosporidia found in Pacific whiting, one being about twice the size of the other, are shown in Figure 6.

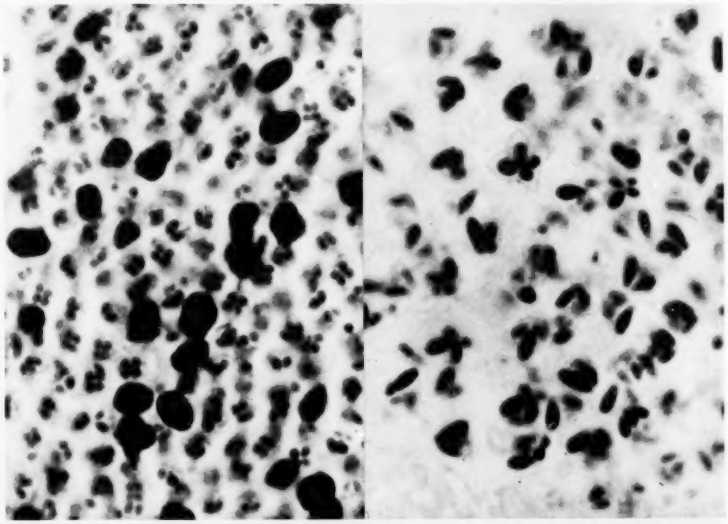

Figure 6.—Histological sections through highly parasitized Pacific whiting showing the two types of myxosporidia: The small *Kudoa* sp. (4-6 μm) and the large *Kudoa* sp. (8-18 μm). The larger, dark-stained bodies associated with small spore are likely a transition or presporulation stage which is periodically seen (540×).

Structural details of the small spore are shown in the electron microscopic enlargement in Figures 7 and 8. The sectional views show two of the four polar capsules, the coiled filaments, and

Figure 7.—Electron microscope enlargement of small spore showing two of four capsules and other structural details (37,500×).

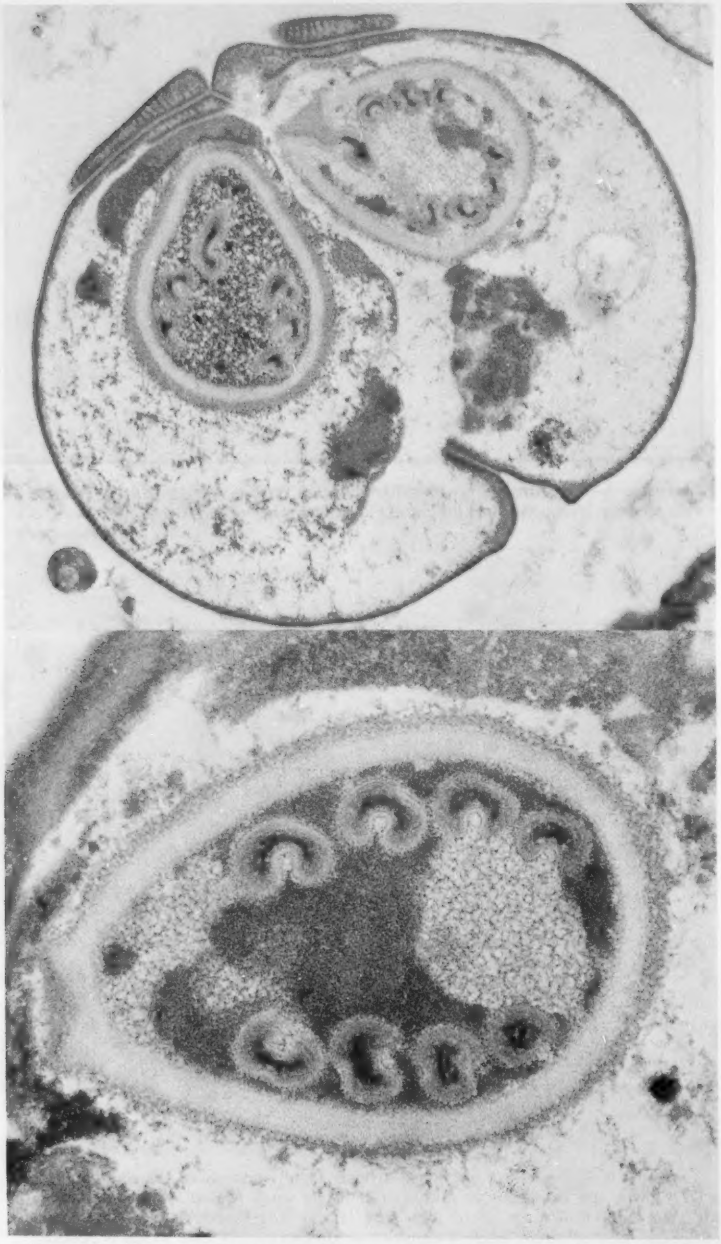

Figure 8.—Electron microscope enlargement of small spore showing two of four capsules and spiral filaments (35,000×).

a very heavy, protective outer spore wall. Exposure of the spore to 5 percent KOH in a wet mount causes a vigorous extrusion of the coiled filament. The spore may extrude one, two, three, or all four of its filaments, one for each capsule. Spores exposed to long-wave ultraviolet light for 2½ hours or to 0.2 Mrad irradiation still retain the ability to extrude filaments on treatment with 5 percent KOH. Similarly, spores frozen over extended periods of time (over 1 year) retain this capability. The spores of cooked whiting lose this capability. Whether this phenomenon is related to spore viability is not known.

Heavily parasitized raw whiting fed to mice over a 6-week period were not found to invade the musculature or any vital organs. The excreta showed the typical spore. Spores from the excreta subjected to 5 percent KOH displayed the typical filament extrusion characteristic it did prior to feeding.

Muscle destruction in parasitized whiting proceeds more rapidly in unrefrigerated than in refrigerated whiting held at 32°F. To examine the various stages of muscle destruction, severely parasitized whiting were held at ambient temperature about 16°C (61°F) and were sampled at 0.5, 7, 31, and 48 hours of storage aboard the RV *Profesor Siedlecki* (August 1977) and preserved for later microscopic and photographic examination.

In samples taken at 0.5 hour of ambient storage, cysts are located intramuscularly and are intact (Fig. 9). Most of the surrounding muscle is normal in appearance.

The samples taken after 7 hours of ambient storage (Fig. 10) still show intact cysts. However, the surrounding muscle is beginning to show structural disorientation.

The samples taken after 31 hours of ambient storage (Fig. 11) show the cyst wall breaking down and discharging its spores, with extensive damage of the surrounding muscle. Spores discharged from the cyst are seen in the intermuscular spaces.

The samples taken after 48 hours (Fig. 12) show few intact, walled-in cysts and the associated vast muscle damage.

We must note, however, that cysts in

Figure 9.—Histological section showing the initial normal relation of the intact cyst and the muscle fiber in severely parasitized Pacific whiting after 0.5-hour storage at ambient temperature of 16°C (61°F) (295×).

Figure 10.—Histological section showing the early phase of muscle disorientation and damage (arrow) with the cyst relatively intact in severely parasitized Pacific whiting after 7 hours of storage at ambient temperature of 16°C (61°F) (295×).

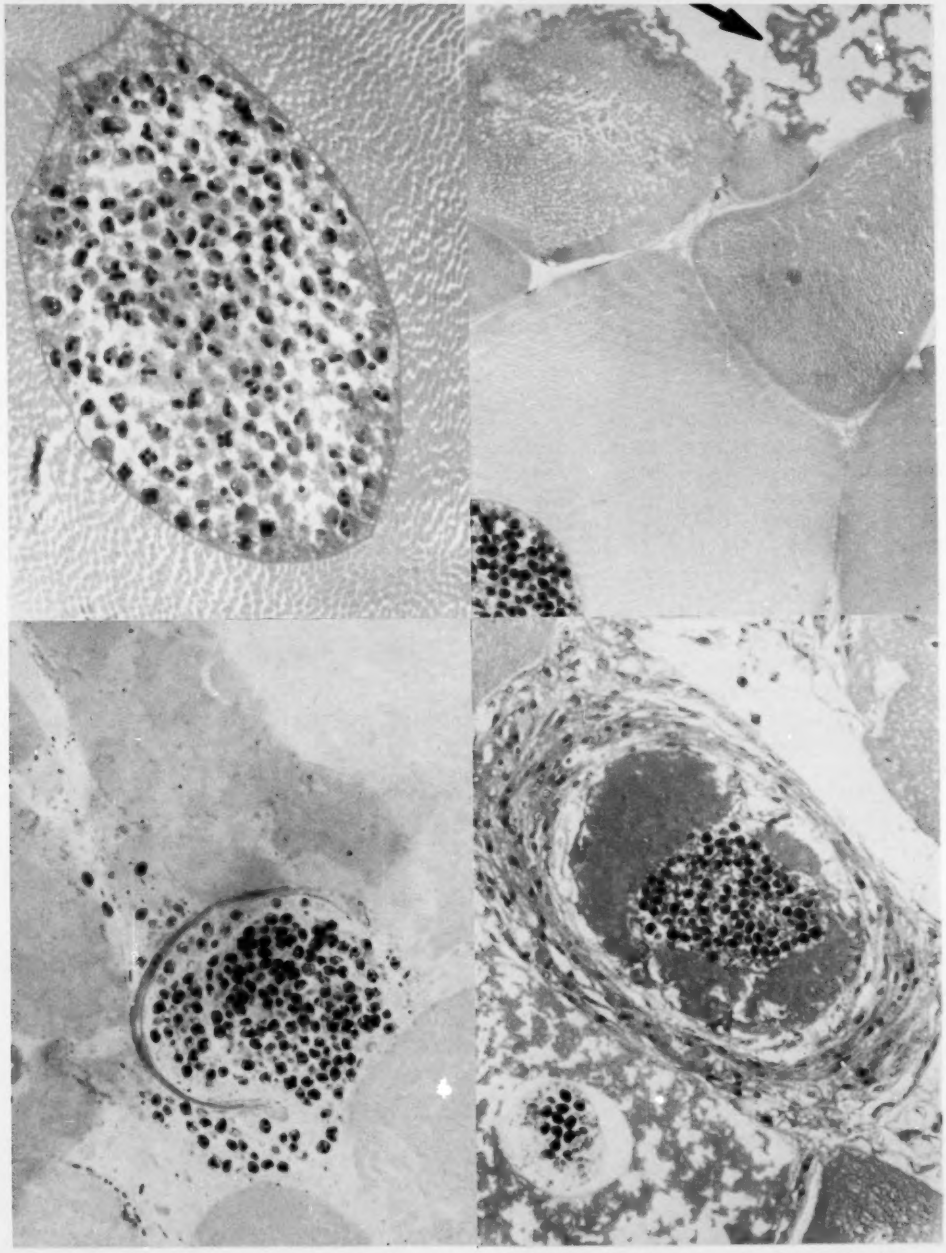

Figure 11.—Histological section showing the cyst wall breaking down with extensive damage of the surrounding muscle and the spores discharged from the cyst in the intermuscular spaces in severely parasitized Pacific whiting after 31 hours of storage at ambient temperature of 16°C (61°F) (295×).

Figure 12.—Histological section showing few intact walled-in cysts with the associated vast muscle damage in severely parasitized Pacific whiting after 48 hours of storage at ambient temperature of 16°C (61°F) (295×).

individual fish are not of the same developmental stage or age and therefore are not uniform in their proteolytic activity, nor are they uniformly distributed. Thus, deterioration and muscle damage will proceed at different rates in different parts of the fish. This can be observed microscopically.

Mechanism of Abnormal Texture Development

Observations over 15 years on the development of abnormal texture in Pacific whiting that has been given various treatments and processed fresh and frozen at sea have permitted us to formulate a working hypothesis. The following findings may be set forth in support of this hypothesis:

1) Early tests showed that steam-cooked subsamples of severely parasitized whiting landed aboard the RV *John N. Cobb* and stored at ambient deck temperature were normal in texture during the first 3 hours but became abnormally soft to mushy after 4 hours of storage, indicating a relatively early onset of the texture problem in severely parasitized fish.

2) Proteolytic activity was demonstrated in severely parasitized whiting aboard the RV *Profesor Siedlecki* in September 1977 within the localized, walled-off parasitic cyst containing the spores and was detected in the blood of severely parasitized whiting but not in the adjacent parasite-free muscle fibers. This suggests that the enzyme is removed from the parasitized muscle fiber by the blood during life, but after death this capacity is lost.

3) Using fresh, severely parasitized whiting with white cysts only and 3-hour iced fish with both white and dark cysts, we observed in collaborative work aboard the RV *Profesor Siedlecki* in August 1977 that the myxosporidian spores separated out by bacterial filter did not generate significant proteolytic enzymic activity during incubated storage at 40°C (104°F) for 6 hours. We concluded that the spores per se were not the source of proteolytic activity after the death of the host fish.

4) The initial level of proteolytic activity per unit of flesh in parasitized whiting was determined in collaborative work aboard the RV *Profesor Siedlecki* in August 1977. We found, after samples were stored in ice for 60 hours or at ambient deck temperature for 36 hours (Schwartz et al., 1978), that proteolytic activity per unit of flesh did not increase significantly. Rather, it appeared to be a fixed amount which spread through the flesh during storage.

5) Microscopic examination of parasitized whiting stored at ambient temperature (RV *Profesor Siedlecki*, September 1977 sampling) showed the muscle and walled-off cysts to be initially intact. As the walled cyst containment gradually deteriorated with time of storage, the surrounding muscle showed increasing proteolytic breakdown (Fig. 9-12).

Therefore, the proteolytic activity within parasitized whiting is hypothesized to be highly localized initially within the walled-in cyst containment, affecting only a very minute portion of the muscle biomass. During subsequent handling, storage, processing, and cooking, the active proteolytic enzyme diffuses out of the cyst, and with the sarcoplasmic and vascular fluids as a carrier, affects more and more of the muscle fiber biomass. The amount of muscle biomass ultimately affected with proteolytic enzyme depends to a large extent on the type of cyst (dark vs. white), the cyst density (severity of parasitization) of the host fish, and the time-temperature handling of the fish. In general, the more rapidly the whiting are chilled, processed, frozen, and cooked, the less fish muscle will be adversely affected with enzyme and the more normal will be its texture. After muscle texture is damaged by enzyme action due to poor storage, extremely rapid cooking is of little value to protect texture. Rapid cooking is of value only when refrigerated storage has been good, and the localized enzyme damage has been minimal. A few typical experiments in support of this hypothesis are presented in the next few subsections.

Texture Evaluation of Live Whiting Frozen in Dry Ice

One of the difficult problems in research on abnormal texture of Pacific whiting has been the wide variance within fish and between fish in the treatment groups, making it difficult to replicate and interpret results. The differences of greatest concern in whiting have been due to the wide variation in parasite incidence and severity of the infection between lots.

To minimize the variance, 18 live whiting were frozen aboard vessel between slabs of dry ice to serve as a quality baseline for superimposing test variables. Each whiting was cut into two lateral halves: One half for microscopic classification of severity of parasitization and the other half for imposing test variables. The half sides were cut into 24-28 3/8-inch slices and placed sequentially into treatment groups as shown in Figure 13. The individual whiting were classified on the basis of severity of infection as follows: 1) None to slight, 2) slight to severe, and 3) severe. Test variables included preparation by the slow oven-cooked and the fast deep-fat-fried methods of whiting portions for texture evaluation. Portions were cooked from the frozen state and after thawing and holding for 1 and 2 days at 33°F.

The results (Table 6), classified according to these categories, show the following: Texture was found to be independent of the treatment for the none-to-slightly parasitized whiting. Texture ratings for the slightly-to-severely parasitized whiting showed insignificant decreases for the various treatments including the slow or oven-cooked and the fast-cooked, deep-fat-fried portions.

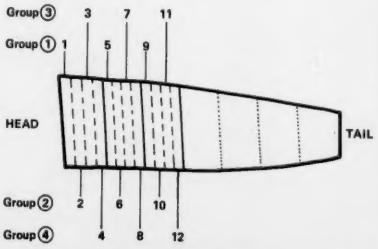

Figure 13.—Sampling sequence for dry-ice frozen Pacific whiting (24- to 28⅜-inch slices, sequentially placed in 4 treatment groups of 6 or 7 slices per whiting per treatment.

Table 6.—Effect of various treatments on the average texture of live Pacific whiting frozen in dry ice (unparasitized to severely parasitized).

Parasite spore[2] intensity	Texture[1]: Dry-ice frozen control, not thawed — Oven[3] cooked	Dry-ice frozen control, not thawed — Deep-fat[4] fried	Thawed, held 1 day at 33°F, refrozen — Oven[3] cooked	Thawed, held 1 day at 33°F, refrozen — Deep-fat[4] fried	Thawed, held 2 days at 33°F, refrozen — Deep-fat[4] fried
None to slight: 1-3 (average for 6 hake)	4.5	5.0	4.8	4.8	4.8
Slight to severe: 3-5 (average for 6 hake)	4.4	4.8	4.3	4.8	4.5
Severe: 5 (average for 6 hake)	3.5	4.7	2.0	3.3	3.0

[1]Texture: 5 = normal to firm; 4 = normal to soft; 3 = soft; 2 = overly soft; 1 = mushy, pasty.
[2]Parasite spore intensity (microscopic wet mount examination of cooked flesh): 1 = none; 2 = trace; 3 = slight; 4 = moderate; 5 = severe.
[3]Oven-cooked samples were heated at 400°F for 18 minutes (slow cooked).
[4]Battered-and-breaded, ⅜-inch-thick frozen slices were deep-fat fried at 385°F for 3 minutes (fast cooked).

Table 7.—Effect of various treatments on the average texture of live Pacific whiting frozen in dry ice (severely parasitized).

Parasite[2] spore intensity	Texture[1]: Dry-ice frozen control, not thawed — Oven[3] cooked	Dry-ice frozen control, not thawed — Deep-fat[4] fried	Thawed, held 1 day at 33°F, refrozen — Oven[3] cooked	Thawed, held 1 day at 33°F, refrozen — Deep-fat[4] fried	Thawed, held 2 days at 33°F, refrozen — Deep-fat[4] fried
Severe: 5	3.5	5.0	2.0-2.5[5]	4.0	3.8
"	1.0-3.0	5.0	1.0	2.0-2.5	1.0-2.5
"	2.0-3.0	4.8	1.0-1.5	2.8	2.0-3.5
"	4.3	5.0	2.0-3.0	3.0	2.0-3.0
"	4.3	4.8	2.0-2.5	3.5	1.0-4.0
"	4.3	3.5	2.0-3.0	4.0	3.8
Overall average	3.5	4.7	2.0	3.3	3.0

[1]Texture: 5 = normal to firm; 4 = normal to soft; 3 = soft; 2 = overly soft; 1 = mushy, pasty.
[2]Parasite spore intensity (microscopic wet mount examination of cooked flesh): 1 = none; 2 = trace; 3 = slight; 4 = moderate; 5 = severe.
[3]Oven-cooked samples were heated at 400°F for 18 minutes (slow cooked).
[4]Battered-and-breaded, ⅜-inch-thick frozen slices were deep-fat fried at 385°F for 3 minutes (fast cooked).
[5]Underscore = unacceptable texture in one or more slices; range indicated.

Texture ratings for the severely parasitized whiting varied significantly according to the treatment and clearly showed the advantage of fast cooking from the frozen state and the texture degradation caused by holding the thawed portions.

Since the severely parasitized whiting are the main source of the texture problem, the data are shown for each of the individual fish (Table 7). The slow oven-cooking of the frozen control produced one or more slices with unacceptable textures in two of the six severely parasitized whiting, but none in the fast, deep-fat-fried whiting. When the whiting were thawed for only 1 day at 33°F, the number of whiting with unacceptable textures increased to six of six when slow oven-cooked, but to one of six when fast cooked. When the whiting were thawed and held for 2 days at 33°F, the number of portions with unacceptable textures increased to four of six, even when deep-fat fried. It is apparent that severely parasitized whiting are highly prone to proteolytic softening depending on their treatment, but that not all severely parasitized whiting are equally affected.

The tests clearly show that variability in the severity of the infection within and between fish will determine their actual predisposition to proteolytic softening during either slow or fast cooking. Poor handling practice will intensify this predisposition, while good handling practice will overcome or moderate it.

Texture Evaluation of Frozen Fillet Block Portions

In this experiment, fillet block portions were prepared at sea from whiting obtained under commercial catching and handling conditions. The whiting were taken between Astoria and Coos Bay, Oreg., about 12 miles off the coast, and over one-third of the fish were found to be 100 percent parasitized on microscopic examination. The objective was to compare 1) the effect of thawing and 1-day storage at 33°F on the texture of portions obtained from whiting filleted and frozen 3-4 hours after catching, and 2) the effect of slow vs. fast cooking. Paired test portions were cut 3/8-inch thick from the frozen fillet block for the controls and treatment (Table 8).

Comparison of 38 portions prepared and cooked from the frozen state by the slow oven-cooked method with 38 portions allowed to thaw for 1 day at 33°F prior to cooking showed a significant increase from one to six portions with unacceptable texture. A similar comparison with paired lots of 39 portions that were fast cooked by deep-fat-frying showed no problems with unacceptable texture in either lot. In spite of the high level of parasitization of these whiting, the portions prepared by fast cooking before and after thawing had textures within the acceptable range in both cases. The results with the slow-cooked portions again demonstrated that the potential to develop the unacceptable texture was present and is a limiting characteristic in holding and cooking the portions.

Table 8.—Texture of cooked fillet block portions prepared from 3-4 hour commercially landed Pacific whiting.

Item	Texture treatments: Oven cooked[2] — Not thawed (control)	Oven cooked[2] — Thawed, held 1 day at 33°F	B/B[3], deep-fat fried — Not thawed (control)	B/B[3], deep-fat fried — Thawed, held 1 day at 33°F
No. of paired portions	38	38	39	39
Texture range[1]	2-5	1-5	4-5	3-5
Avg. texture	4.4	3.6	4.9	4.4
No. of unacceptable textures of 1 and 2	1	6	0	0

[1]Texture: 5 = normal to firm; 4 = normal to soft; 3 = soft; 2 = overly soft; 1 = mushy, pasty.
[2]Oven-cooked samples were heated at 400°F for 18 minutes (slow cooked).
[3]Battered-and-breaded ⅜-inch-thick frozen slices were deep-fat fried at 385°F for 3 minutes (fast cooked).

Effect of Refrigerated Storage on the Texture of Commercial Fillets

Some processors have considered fresh fillet marketing of whiting. Typical data from one study using 2-day-iced commercial fillets is presented to indicate the texture problem in fresh fillet marketing. The fillets were carefully screened and divided into visually normal and parasitized fillets and frozen.

Paired subsections were cut from each fillet and slow oven-cooked initially and, to simulate marketing conditions, after thawing and holding for 5 days at 34°F. The texture ratings of the normal and parasitized fillets (Table 9) show clearly the extent of the problem. The normal fillets had acceptable texture initially and after 5 days of refrigerated storage at 34°F. In contrast, the parasitized fillets initially had 9 of 42 fillets with unacceptable soft texture and, after 5 days of storage at 34°F, had 16 fillets with unacceptable texture. This experiment emphasizes the risk of marketing whiting in fresh fillet form, since it is impractical to cull out the severely parasitized whiting. As shown earlier, the fast-cooked or deep-fat-fried portion-type product appears to be the only feasible option to eliminate a high percentage of product rejected for unacceptable, soft to mushy texture.

Table 9.—Effect of refrigerated storage on the texture of 2-day-iced commercial fillets (normal vs. parasitized).

	Number in each texture category			
	Normal fillets		Parasitized fillets	
Oven-cooked[1] texture ratings	Initial	After 5 days at 34°F, refrozen	Initial	After 5 days at 34°F, refrozen
5 = Normal to firm	32	28	8	7
4 = Normal to soft	19	21	21	18
3 = Soft	0	2	4	1
2 = Overly soft	0	0	3	5
1 = Mushy, pasty	0	0	6	11
Total fillets[2]	51	51	42	42

[1]Oven-cooked samples were heated at 400°F for 20 minutes.
[2]Each of the 51 normal and the 42 parasitized fillets were cut into 3 or 4 paired subsections for the initial and 5-day test groups.

Conclusions

The abnormal muscle texture in Pacific whiting is caused by a myxosporidian-induced proteolysis. The latent potential for proteolytic textural softening in whiting, due to the presence of myxosporidian cysts of variable intensity, appears to be an intrinsic characteristic of the Pacific species. The enzyme appears to be highly localized within the cyst and has little effect on the muscle fibers if the fish have been rapidly chilled, processed, and rapidly cooked. We recommended that whiting be marketed as a fast-cooked or deep-fat-fried, portion-type product, limited to about 3/8-inch in thickness.

Acknowledgments

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The "at sea" work was carried out aboard the RV *John N. Cobb* and MV *Willapa Bay* by Max Patashnik, aboard the RV *Profesor Siedlecki* by Pat Hunter, George Kudo, and Glenn Roberts; aboard the RV *Forerunner* by Pat Hunter, Harold Barnett, George Kudo, and Max Patashnik; and aboard the MV *Kupreanof* by Pat Hunter and Harold Barnett.

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Radio Telemetry of Hawaiian Green Turtles at Their Breeding Colony

ANDREW E. DIZON and GEORGE H. BALAZS

Andrew E. Dizon was with the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812 and George H. Balazs is on an Intergovernmental Personnel Assignment from the Hawaii Institute of Marine Biology, University of Hawaii, to the NMFS Honolulu Laboratory. Dizon is now with the Southwest Fisheries Center, NMFS, NOAA, P.O. Box 271, La Jolla, CA 92038.

Introduction

More than 90 percent of the breeding activity of the Hawaiian green turtle, *Chelonia mydas,* occurs at a small atoll situated about midway along the 2,450 km length of the Hawaiian Archipelago (Fig. 1). Here, principally during May and June, turtles gather to copulate and nest.

Because of the specificity of the marine turtle's choice of breeding sites and times, any significant disturbance by man during this period could have profound effects upon the population. Yet little is known about the marine habitat of the animals during this period. Most of the work (Balazs, 1976, 1980) has involved hauled-out turtles when

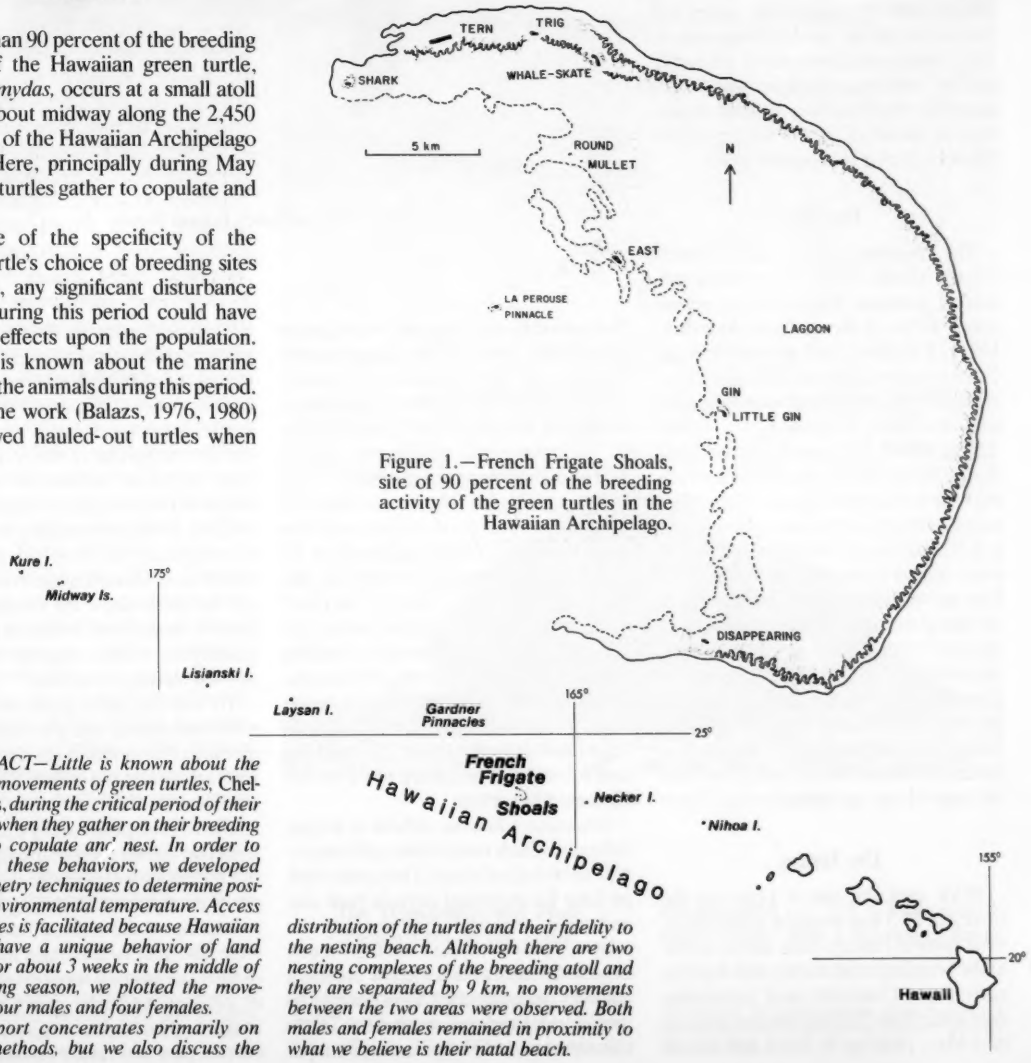

Figure 1.—French Frigate Shoals, site of 90 percent of the breeding activity of the green turtles in the Hawaiian Archipelago.

ABSTRACT—Little is known about the range and movements of green turtles, Chelonia mydas, *during the critical period of their life history when they gather on their breeding grounds to copulate and nest. In order to investigate these behaviors, we developed radio telemetry techniques to determine position and environmental temperature. Access to the turtles is facilitated because Hawaiian* Chelonia *have a unique behavior of land basking. For about 3 weeks in the middle of the breeding season, we plotted the movements of four males and four females.*

This report concentrates primarily on tracking methods, but we also discuss the distribution of the turtles and their fidelity to the nesting beach. Although there are two nesting complexes of the breeding atoll and they are separated by 9 km, no movements between the two areas were observed. Both males and females remained in proximity to what we believe is their natal beach.

they are readily visible to the investigator. Where the turtles go between the periods when they crawl out on the beach remains a mystery. Yet it is when the turtles are in the nearshore waters that the greatest potential for conflicts with humans exists. Managers of the habitat must be informed about the distribution of the turtles during the breeding period in order to avoid potentially damaging interactions.

The purpose of our study was to develop radio telemetry techniques to locate turtles throughout their breeding habitat and to study their range and behaviors during the breeding period. This report will concentrate primarily on the tracking technique and briefly describe the breeding habitat range. Specific details of their behaviors will be the subject of a subsequent paper.

Green turtle at French Frigate Shoals.

The Site

The breeding atoll is called French Frigate Shoals (FFS). It is a crescent-shaped platform which rises to within about 40 m of the surface (Amerson, 1971). Extensive reef growth has occurred on the platform and now there are about 12 permanent islands, 4 with well-established vegetation.

Tern Island, the largest, was modified during World War II to serve as a refueling base for aircraft support of the Midway Campaign. It was later used by the U.S. Coast Guard which maintained a loran station there until 1979. The U.S. Fish and Wildlife Service now maintains the island with several resident biologists. French Frigate Shoals as well as most of the other islands of the northwestern segment of the archipelago are units of the Hawaiian Islands National Wildlife Refuge and are designated officially as a Research Natural Area. Tern Island was the base of our operation.

The Turtles

Work over the past 8 years on the turtles of FFS has revealed much about their natural history. The turtles arrive at the breeding atoll during mid-April to early June. Courtship and copulation take place then. Nesting starts as early as mid-May, peaking in June, and has all but ceased by mid-August. Nesting takes place over most of the larger stable islands with approximately 55 percent nesting at East Island and 35 percent at Whale-Skate/Trig Island complex (Fig. 1). As many as six egg clutches may be laid by a single female during one season but the mean is 1.8. The interval between oviposition in turtles that nest more than once averages 13 days, ranging from 11 to 18 days. Females journey to the breeding atoll once every 2 or more years; males every 1 or more years. The turtles come from and return to feeding pastures located in the rest of the archipelago. These long-range precise migrations to and from the breeding islands have been documented by the marking and subsequent recapture of 52 turtles (Balazs, 1976, 1980).

Hawaiian *Chelonia* exhibit a unique behavior which make them quite amenable to biological study. The turtles bask on land for extended periods both day and night, and while basking they are relatively easy to capture and tag. French Frigate Shoals is one of eight breeding colonies designated for high priority by the World Conference on Sea Turtle Conservation (1979) by reason of unique ecology and isolation. Balazs (1980) in a study period extending over 8 years has tagged over 140 adult male and 528 adult female turtles. Yet mark-and-recapture studies are not well suited for delimiting the critical habitat of the turtles during their sojourns within the nearshore waters between nesting or basking period on land. Extensive trapping in the water to recapture the marked animals is impractical. Identification marks painted on the shells allow for visualization of limited movements, but most turtles are quickly lost to the observer when they are not basking or nesting.

We felt that radio telemetry to determine movements was the least intrusive method of determining positions during trips away from the beach. We attached small transmitters to the turtle's carapace and fixed their positions by triangulation from two distant receiving stations. With this technique we were able to determine positions of the turtles during basking or swimming on the surface. As a result we were also able to ascertain the fraction of time the animals spent on the surface or on land and how much time submerged. These data are necessary to correct past and future census informa-

tion since, at any one time, only a fraction of the turtles are visible to an observer. Our transmitters were sensitive to the environmental temperature so that we could determine whether turtles were basking on land or swimming at the surface. This information as well as other performance parameters of the turtles will be the subject of a subsequent paper. For now, we are interested in the techniques and range.

Past Telemetry Work Within Breeding Colonies

"One of the conspicuous gaps in the behavioral ecology of the green turtle . . . is the lack of data on the movements of females during the 12-14 day periods between their emergences at the nesting beach" (Carr et al., 1974). Actually, a number of studies have been conducted but more data still need to be generated (Carr, 1967a, 1967b, 1972; Baldwin, 1972; Meylan, 1978, in press; Standora et al., 1979; Feazel, 1980; Mortimer, 1981). The internesting movements of two other species have also been investigated (loggerheads, *Caretta caretta*, Murphy, 1979; Stoneburner, 1979; and Kemp's ridley, *Lepidochelys kempi*, Pritchard, 1980). All of these data are characterized by few subjects, no males, and short tracking periods. Most utilized a towed drogue usually equipped with a pennant and light. Sometimes sophisticated satellite transmitters were employed (Stoneburner, 1979; Daniel, 1980). Thus technical equipment is not cause for the information gap. Nor is size a problem since in fact telemetry devices (both radio and acoustic) are available for use on juveniles and hatchlings (Ireland, 1979a, 1979b; Garmon, 1981; Timko and DeBlanc, 1981; Stinson and Fritts[1]). Our goal was to deploy radio transmitters on both male and female turtles, track them throughout a significant portion of the reproductive period, and collect as many distributional, behavioral, and physiological data as possible.

[1]M. L. Stinson, 1553 Avocado Drive, Vista, CA 92083; T. Fritts, National Fish and Wildlife Laboratory, Tulane University, Belle Chasse, LA 70037, pers. commun.

Green turtle basking at French Frigate Shoals.

The Transmitters and Their Deployment on the Turtle

The 2 m (149 mHz) transmitters we employed were purchased as "off-the-shelf" items from Telonics, Inc.[2] Mesa, Ariz., (Fig. 2). These were hermetically encapsulated 7.5 × 4 × 3 cm, round-edged boxes with a mounting flange

[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

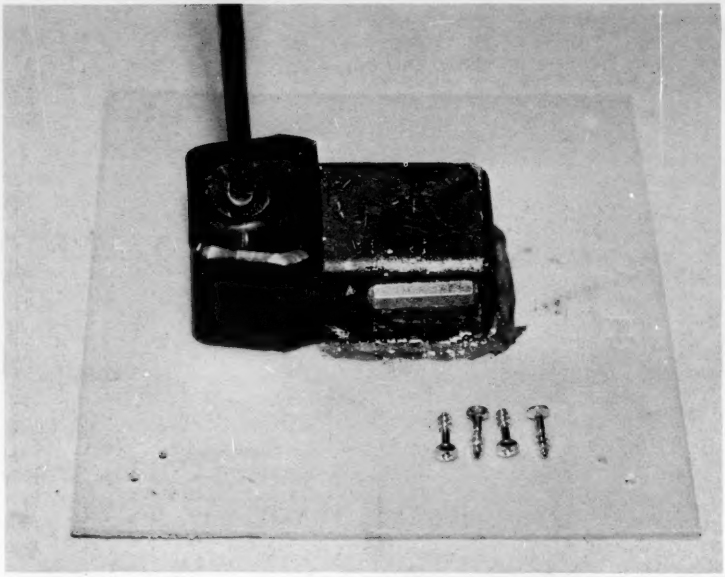

Figure 2.—The transmitter and its mounting plate. Note the thread design on the bone screws and the magnet which is used to turn the transmitter off.

attached to the bottom. A flexible quarter-wavelength stub antenna emerged from the front and extended 46 cm. The transmitters were temperature-sensitive; as the package warmed, the pulse rate increased. We observed an effective range of over 10 km when the transmitter package was awash at the sea surface and the receiving antenna was elevated about 9 m.

Since we were interested in following the animals for a long period, a reliable attachment method for the transmitter was critical to the success of the project. Hawaiian *Chelonia* have a habit of resting within coral caves and under outcroppings. A tethered transmitter would be useless and unless provided with a breakaway link, would pose a danger to the animals.

The study areas of the other workers reported earlier were generally free from such obstructions. Thus we had to attach the transmitter directly to the shell. To conform to the curvature of the shell and yet provide a wide mounting base, the transmitter was secured to a 15 × 15 cm, 0.6 cm thick piece of high molecular weight polyethylene (Fig. 2). This very tough but flexible plastic easily conformed to the carapace.

The plastic was attached to the shell with surgical bone screws fabricated for orthopedic repairs (mallolar style, Zimmer Inc.). The screws were made of a proprietary alloy which made them unreactive within the tissues of the shell and impervious to the seawater. The thread of the screw was designed to provide great holding power with the very shallow penetration which we required. Experiments with captive turtles demonstrated that the attachment technique was sound but the silvery coating of the transmitters was particularly appealing to fellow tank-mates and numerous biting attacks were made on the units. This problem was eliminated by camouflaging the transmitters with roofing tar and sand.

The actual attachment was choreographed and refined until it took less than 45 seconds. At dusk, the basking turtle was stealthily approached by one of us and turned over on its back. A short time later, after nightfall, the chosen turtle was propped up at about a 45° angle (head up) while still on its back. Sand was removed to allow room to work under it. A battery-driven drill, equipped with a counterbore bit and a positive stop to limit the depth of the hole was used to make four pilot holes in the carapace. The plastic plate, already equipped with the transmitter, was then screwed into place. The magnet holding the transmitter turned off was removed and a radio check back to the receiving stations was made to ascertain that everything was working. Cold-process roofing tar was applied to the transmitter, plate, and screws and then covered with sand and the turtle righted. The bionic *Chelonia* immediately scrambled to the ocean and swam off and the tracking began (Fig. 3).

The Receivers

We employed two separate receiving stations in order to fix positions of the transmitter-carrying turtles. One was located in the old Coast Guard facility on Tern Island; the other, 13 km away at East Island. Tern Island was the primary receiving station which monitored continuously. The East Island station was only active at 6-hour intervals: 0300, 0900, 1500, and 2100. During that time period bearings were obtained on each of the turtles and their positions plotted.

The receiving equipment at Tern Island consisted of two receiver systems: An omnidirectional antenna connected to a receiver with a frequency scanner and a highly directional antenna connected to a receiver with a signal processor for digital measurements of period and signal strength. The East Island station had a highly directional antenna and a receiver equipped with a processor. The directional antenna at Tern Island (mounted about 9 m off the ground) was positioned with a motorized antenna rotor while the one at East Island (5 m off the ground) was rotated by hand. Bearings were determined from the antenna rotor control box at Tern Island and a compass mounted on the mast at East Island. Under all but the weakest signal conditions, our accuracy of bearing was about ±5°.

In addition to bearing fixes every 6 hours, the station at Tern Island sampled

every 10 minutes throughout the whole study period and continuously during three 24-hour periods. The frequency scanner was programmed to scan through the transmitter frequencies. When a signal was detected, the pulse rate was read to determine temperature of the transmitter. These data will be presented in a subsequent paper but it should be mentioned that the amount of time spent on the ocean surface when the signal could be detected was usually less than 1 minute. Thus not much time was available for us to measure pulse rate and fix position.

Every 6 hours the receiving equipment at East Island was turned on. When a turtle signal was detected at Tern Island by the scanner-equipped receiver, the information was relayed to East Island and both stations attempted to fix the bearing of the signal with the directional antennas. Sometimes it was impossible to obtain fixes on all of the turtles. We would hear the signal from a given turtle, but it would not stay on the surface long enough to get an accurate fix.

Residence Times

Four males and four females were equipped with transmitters. For convenience, the turtles were identified by the last three digits of the frequency of their transmitters. For instance, the male equipped with a 149.350 mHz transmitter was known as male 350 (Table 1). This animal was originally tagged with a flipper tag on 31 July 1975 while basking on Whale-Skate Island and recovered on 12 April 1976 and 25 September 1977 while again basking on the same island. The turtle was captured again on Whale-Skate Island and the transmitter attached on 8 June 1980.

Male 540 (149.540 mHz) was originally tagged on 3 May 1979 while basking on Trig Island and found again a day later in the same place. Copulation injuries were noted at the time. The transmitter was attached on 9 June 1980 while on Whale-Skate Island.

Males 360 and 510 had no previous tagging history and had transmitters attached on 8 and 9 June, respectively, while they were on Whale-Skate Island.

Female 200 was originally tagged on 22 March 1968 while basking on Southeast Island, Pearl and Hermes Reef (Fig. 1). The transmitter was attached while the animal was basking on Trig Island 9 June 1980.

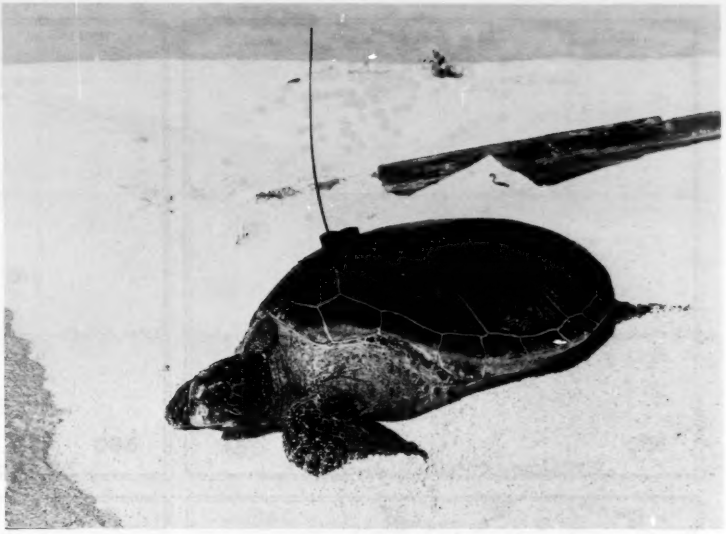

Figure 3.—Transmitter-equipped female 200 returning to the ocean after gear attachment.

Table 1.—Tagging and tracking data. Tagging data are from Balazs' long-term study of the green turtles of Hawaii (Balazs, 1980). The "off" date refers to the date when the last signal was received from the transmitter, WS = Whale-Skate Island, TRIG = Trig Island, and EAST = East Island.

Tagging	First tagging	First recovery	Second recovery	Transmitter deployment On	Off	Days
Male 350						
Date	7/31/75	4/12/76	9/25/77	6/08	9/04	73
Location	WS	WS	WS	WS		
Male 360						
Date	No previous record			6/08	6/27	19
Location				WS		
Male 510						
Date	No previous record			6/09	6/14	5
Location				WS		
Male 540						
Date	5/03/70	5/04/79		6/09	8/12	49
Location	TRIG	TRIG		TRIG		
Female 200						
Date				6/09	6/30	21
Location	3/22/68			TRIG		
Female 450						
Date	7/10/70	7/05/74		6/08	11/13	143
Location	EAST	EAST		WS		
Female 490						
Date	6/19/79	6/29/79		6/09	8/07	60
Location	WS	WS		WS		
Female 530						
Date	No previous record			6/09	8/10	63
Location				TRIG		

[1]Southeast Island, Pearl and Hermes Reef (Fig. 1).

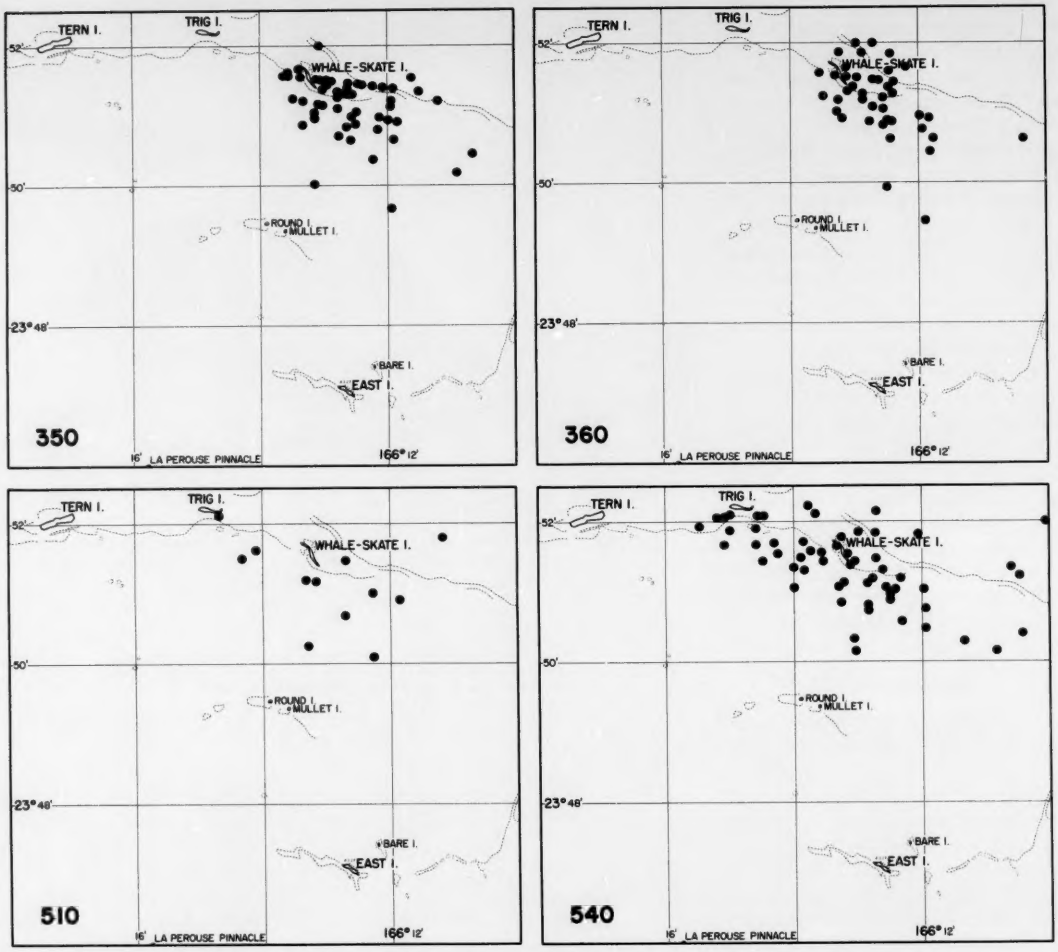

Figure 4.—Distribution of position fixes of the male turtles. Male 510 left the breeding colony about midway into the tracking period.

Female 450 was tagged first on 10 July 1970 and recovered again 5 July 1974 while nesting on East Island. The transmitter was attached on 8 June 1980 while it was basking on Whale-Skate.

Female 490 was first tagged on 19 June 1979 while it was on Whale-Skate and recovered again in the same place 10 days later. The transmitter was attached on 9 June 1980 while it was on Whale-Skate Island.

Female 530 was equipped with the transmitter on 9 June 1980. It had no previous history of tagging.

Our monitoring program was continued until 30 June 1980. Then the station at Tern Island was manned sporadically after our departure by caretaker personnel in order to see how long it was possible to maintain contact with the transmitter-equipped turtles. Of course, when a signal disappeared, it could either mean the turtle departed the colony or had shed the equipment. One transmitter (from female 490) was discovered off Whale-Skate Island in about 2 m of water in June of 1981. The screws were still in the plate and evidenced no sign of corrosion. Female 450 was found nesting on East Island in June 1981 without a transmitter; the small screw holes in the carapace were clean and without any sign of infection. So the attachment method is safe for the turtles and the equipment is eventually shed.

Table 1 also provides information on the length of time signals were heard from the turtles. The signal from male 510 disappeared first. We think it left the breeding colony because its last position was fixed on 14 June far outside the eastern fringing reef. Male 360 was last

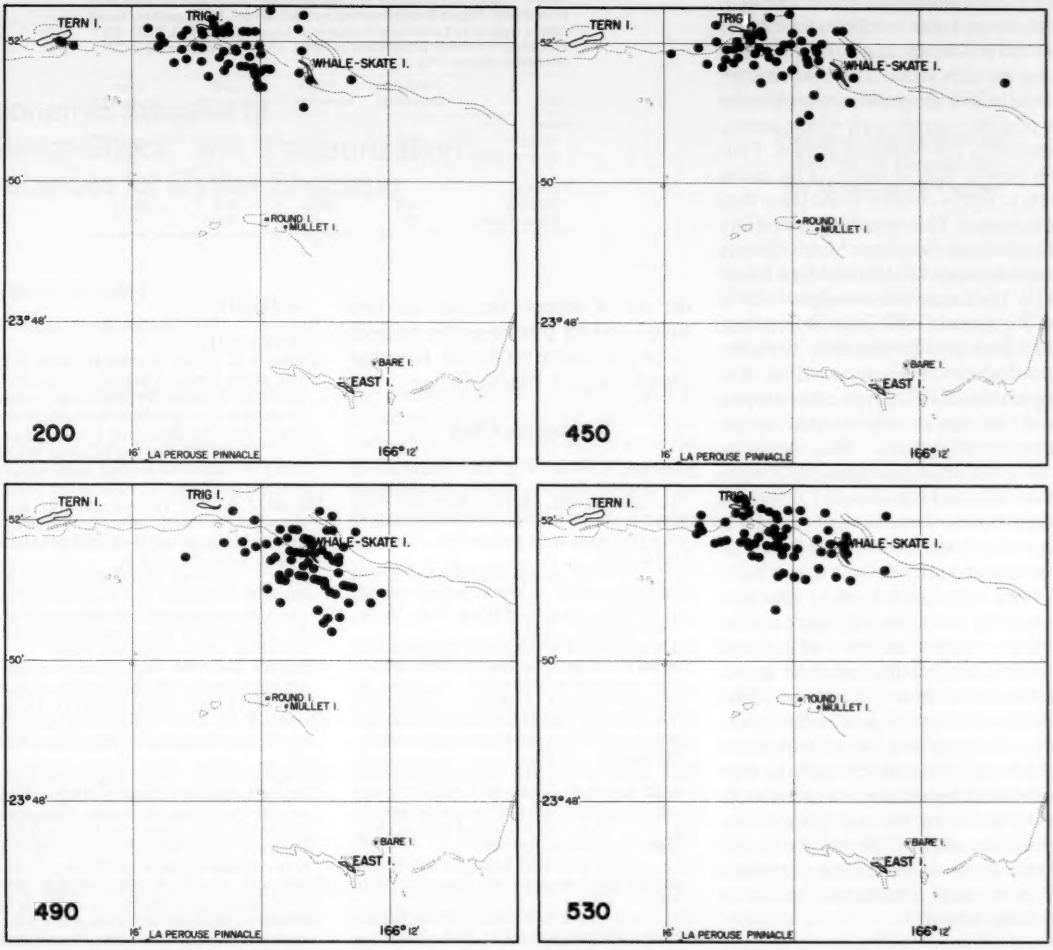

Figure 5.—Distribution of position fixes of the female turtles. Female 200 regularly came to Tern Island to nest.

heard from on 27 June. Female 200 came to Tern Island to nest twice. At the second nesting we decided to remove the transmitter and evaluate its condition and take a close look at the screw wounds. Both the turtle and the transmitter were fine. Our last transmission from her was on 30 June. She was later spotted again nesting on Tern Island on 17 July.

The other five turtles (350, 450, 490, 530, and 540) were all still transmitting when the field party left Tern Island on 30 June.

Females 490 and 530 remained in the colony until the middle of August, leaving on the 7th and 10th. Male 540 left on the 12th of the same month. Male 350 remained another month and was last heard from on 4 September. Female 450 remained the longest in the breeding colony (signals were heard until 13 November). She is likely a permanent resident of FFS.

Habitat Utilized

Our results show that the nearshore habitat of males and females at the breeding colony is in proximity to the basking and nesting islands near where they were captured (Fig. 4, 5). While understandable perhaps for the females, it is curious that the males adhere so closely to the nesting beaches. East Island remains the nesting site for 55 percent of the FFS-breeding turtles. Nevertheless we never observed our turtles traveling the 9 km south to the East Island area. Clearly, there is a strong evolutionary bias for a female to return to the same nesting beach year after year. Since the beach was adequate for

her mother and for her as a hatchling, it is highly probable it will be adequate for her and for her hatchlings. But the males have no such stake. The best strategy would be to impregnate as many females as possible regardless of which nesting beach they will eventually employ. Thus it is curious that the ranges of the males were so tightly coupled to the place they were tagged. This specificity apparently extends over the years. Male 350 was originally tagged on Whale-Skate Island in 1975 and male 540 was tagged in 1979 on Trig Island. Table 2 details previous records of year-to-year visits by males and females to the various islands. The approximately 13-20 percent straying could be due at least in part to the permanent residents. They seem, as female 450 shows, to make use of more of the reefs and beaches of FFS. She was heard from well into November and was spotted several times on the beach at East Island during the summer of 1981.

Thus, our results strongly infer that imprinting to the nesting beach and its environs occurs in both males and females and that this response seems permanent at least over several years. These results also emphasize the importance of maintaining the utilized marine habitat and the nesting beach as free from disturbing influences as possible. It is imperative for the well-being of the population that no alterations in the habitat be made since once imprinted the green turtle is unlikely to switch its breeding habitat.

Table 2.—Specificity of returns by male and female turtles to listed areas within the French Frigate Shoals breeding grounds (Balazs, 1980). Data are based upon a tagging and subsequent recoveries from 1970 to 1980. TRIG-WS = Trig Island and Whale-Skate Island complex, EAST = East Island, and GIN = Gin Island complex (Fig. 1).

Item	TRIG-WS same/stray	EAST same/stray	GIN same/stray	Total same/stray
Males				
Number	33/8	16/2	0/0	49/10
Percent stray	24	12	—	20
Females				
Number	15/5	68/3	0/3	83/11
Percent stray	33	4	100	13

Acknowledgments

Our telemetry field team also included Causey Whittow, Howard A. Jemison III, Steven Kramer, Susan and Robert Schulmeister, Ruth Ittner, and Elizabeth Flint. Each of these individuals made valuable contributions to the project. We also want to express our appreciation to the U.S. Fish and Wildlife Service for the use of support facilities on Tern Island, and for permitting the research to be conducted within the Hawaiian Islands National Wildlife Refuge.

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Economic Analysis of "Steam-Shock" and "Pasteurization" Processes for Oyster Shucking

JOHN W. BROWN

Introduction

"Steam-shock" is an oyster shucking process that uses steam to relax the oyster's adductor muscle, causing the oyster's shell to gap just enough to allow a shucking knife to be inserted without physical force. Inserting the knife without first prying the shells apart or breaking the bill of the shell saves the shucker's effort. Reducing effort and eliminating unnecessary motions translate directly into increased productivity. The increase in labor productivity has been estimated between 20 and 35 percent (Tanchoco and Coale, 1980). This paper presents an analysis of the costs and returns from the installation of the shucking process as in integral part of the operation of an existing oyster-shucking house.

The term "steam-shock" is used here instead of "steam-shucking" to avoid confusion with an older process that uses steam to cook the oyster meats, after which they are mechanically shaken out of their shells. Instead of cooking the meats, the steam-shock process exposes the oysters, still in their shells, to live steam only long enough to raise the temperature of the meat to about 120°F. This takes from 90 to 150 seconds, depending on the nature of the oysters and the temperature of the steam, and is achieved by carrying the shell stock through a steam tunnel, either on a flat conveyor belt or in a bucket hung from an overhead monorail. The conveyor belt method has been chosen for this analysis because it provides a more uniform exposure of the oysters to the steam than the monorail method. Steam-shocking produces a meat that is considered raw and is sold as such in the market.

The steam-shock process has a second advantage in that it can produce a reduction in the natural microflora present in the oyster when combined with rapid chilling of the meats (Wiley, 1980). This process also has the advantage that it can be used to produce a pasteurized product by heating the meats to about 140°F (Goldmintz et al., 1978). The pasteurization process in this paper is simply a variation of the steam-shock process in which the meats are heated to the higher temperature. This variation will be covered in the economic analysis.

The industrial trials with the steam-shock process were carried out by the J. W. Ferguson Seafood Company[1] in Remlick, Va., in 1977. Ferguson allowed knowledge of the process to spread and several other companies have adopted the process. Goldmintz et al. (1978) reported on the development of the pasteurized oyster product in 1978. The Virginia Polytechnic Institute and State University Sea Grant Advisory Service formed a multidisciplinary team to develop the new steam-shock technology in 1978. This led to a symposium in May 1980 and the publication of its proceedings (Huang and Hebard, 1980).

John W. Brown is on an IPA appointment from the South Carolina Sea Grant Consortium to the Southeast Regional Office, National Marine Fisheries Service, NOAA. He is stationed at the Charleston Laboratory, Southeast Fisheries Center, NMFS, NOAA, P.O. Box 12607, Charleston, S.C. 29412-0607.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Principal Assumptions and Analysis of Benefits for the Steam-Shock Process

The analysis presented in this paper rests on the primary assumption that the factor limiting output for the oysterhouse is the number and productivity of its oyster shuckers. The increase in the shuckers' productivity due to the adoption of the steam-shock method is assumed to be 30 percent and is the primary benefit of the process (Tanchoco and Coale, 1980). This is within the range of the increase in oyster-shucking labor productivity commonly attributed to the adoption of the steam-shock process.

The analysis further assumes that the number and productivity of the shuckers continue to be the limiting factors in determining the output of the oysterhouse. The assumption of excess capacity in all factors other than shucking labor allows the production overhead costs to be fixed. Only those costs for items such as the number of cans that vary directly with the level of production and the cost of the steam tunnel then remain relevant to the decision regarding the installation of the steam tunnel. Because the oyster shuckers are normally paid on a piecework basis, it is not possible for the oysterhouse owner to directly recoup the costs of the steam-shock process from the increased labor productivity. Thus, it is necessary for the owners to recover their increased costs by spreading the fixed cost over a larger production. If the additional costs of installing and operating the steam process are less than the reduction in fixed costs, then the steam-shock process is taken to be a viable investment.

A second benefit from the steam-shock process is the potential for increasing the numbers of oyster shuckers. Because they are paid on a piecework basis, the higher productivity would result in increased earnings for the shuckers; this should then result in an increased labor supply for the industry. The process also lessens the skill required to shuck

oysters, because the need to force open the shells is no longer present. This allows new oyster shuckers to rapidly gain proficiency and to achieve full earning power quickly. The increase in labor supply will not be subject to analysis in this paper. The focus instead is on the cost savings from spreading the fixed costs over the larger production and the conditions necessary for the economic viability of the steam-shock product. In areas of labor shortages, however, the process may be adopted for labor reasons alone.

Two other benefits of the process are the savings that could result from the use of a cheaper grade of oysters for shucking and the potential for longer shelf life of the product. The steam-shock oysterhouses in Virginia occasionally use a grade of oysters called "snaps." The reason for the term and for the lower price is because the thinner shells will occasionally snap or break during the cold shucking process. Normally, shuckers will refuse to work with this grade of oyster, thus, it is obtainable at a discount on the market. The second source of savings could result from the potential for a longer shelf life for the oysters. Goldmintz et al. (1978) demonstrated this extended shelf life in their work on the pasteurized oyster. This possibility will be discussed later in this paper.

Cost Estimation

The costs of installing and operating the steam tunnel must be weighed against the benefits mentioned. The costs of purchasing and installing the necessary equipment are proportional to the processing capacity desired. The capacity of the steam tunnel is determined by its size, the temperature and volume of the steam, and the nature of the shell stock. A steam temperature of 180°-190°F and an exposure time of 90 seconds is recommended (Mashburn, 1980). Once the period of exposure to the steam has been fixed, the length of the tunnel determines the speed for the conveyor belt. The volume of shell stock the tunnel can handle in any period can be determined based on speed of the belt, width of the belt, and thickness of the shell stock covering the belt, as by the following equations:

Speed × width × thickness = volume/time, or equivalently,

Length/time × width × thickness = volume/time.

For example, a tunnel 12 feet long and 24 inches wide with a covering 1-inch thick of oysters and a steaming time of 1.5 minutes has a capacity of 2,300 cubic inches/minute of shell stock or 64 U.S. standard bushels/hour.

The U.S. standard bushel is 2,150.4 cubic inches, which differs from most state bushels. The size of bushels used by the southeastern states is listed in Table 1. The sizes of these bushels vary by almost twofold, creating confusion in the market. In many instances the U.S. standard is already used in interstate trade, so that one must be sure of the volume of the bushel in local use.

Table 1.—U.S. bushel capacities.

Item	Capacity (cu. in.)	Item	Capacity (cu. in.)
U.S. Standard	2,150.4	Georgia	3,214.1
Maryland	2,800.7	Florida	3,214.1
Virginia	3,003.9	Alabama	2,826.2
N. Carolina	2,801.9	Mississippi	2,821.2
S. Carolina	4,071.5	Louisiana	2,148.4
		Texas	2,700.0

The meat yield of the shell stock must be known to convert shell stock capacity to volume of meats per unit time. The meat yield varies substantially over the course of a year, depending upon the season and location, the size of oysters, and the nutritional quality and the salinity of the harvesting waters. Obviously, the meat yield will change the capacity of the steam tunnel. Diagrammed in Figures 1 and 2 are relationships between tunnel length, width, and meat yield in determination of the output of the tunnel.

The cost in this paper of installing the steam-shock process in an existing oysterhouse is based on the cost of the purchase and installation of a mesh-type conveyor, with an insulated aluminum box surrounding it, and pipe to carry the steam to the system. The oysterhouse is assumed to have enough space available for installation of the system.

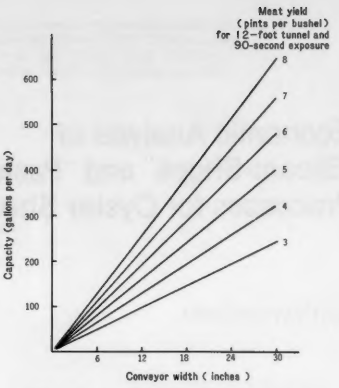

Figure 1.—Steam tunnel capacity vs. conveyor width.

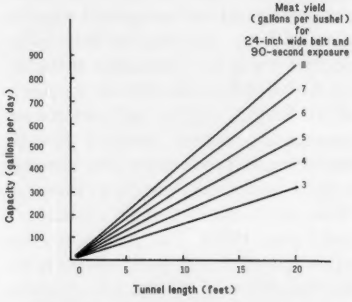

Figure 2.—Steam tunnel capacity vs. conveyor length.

The cost of the steam tunnel is a function of its size. The cost of the basic tunnel with a belt width of 24 inches and 12 feet long is estimated as $6,600, including installation. The cost per foot increase or decrease in length is estimated to be $200. The cost of a 30-inch belt width is estimated to be 112 percent of the cost of a 24-inch belt width, and the cost of an 18-inch width is estimated at 90 percent of the cost of the 24-inch belt width (Wiltse, 1979). Three standard lengths—8, 12, and 20 feet—were used, yielding a choice from nine tunnel sizes. If installation of a boiler sufficient to power the system is needed, the estimated additional cost is $8,000. Many

oysterhouses, however, will already have sufficient boiler capacity. The capital costs are depreciated on a straight-line basis over an 8-year period with an interest rate of 18 percent. The length of the operating season is taken to be 150 working days, or about 30 weeks.

The results of calculations for assumed oysterhouse capacities from 50 to 400 gallons per day (GPD) are shown in Table 2. The range of output increases from 65 to 520 GPD when the 30 percent increase in productivity as a result of steam-shock processing is included. The third column shows the least expensive of the nine tunnel sizes capable of handling the output at a meat yield of 5 pints/U.S. standard bushel.

The assumed costs related to fuel consumption for each of the plant sizes are shown in Table 3. The second column shows the fixed tunnel costs per year including depreciation and interest costs for the tunnel purchase. The last two columns show the total costs per day of the steam-tunnel operation with and without the purchase of the boiler. The fact that the estimated costs do not increase as rapidly as the oysterhouse's physical capacity is important to note, because it introduces new economics of scale into the industry.

The results of this slower rate of cost increase can be seen in the economics of scale in Tables 4 and 5. The second column in both tables shows the new costs per additional gallon of oyster meats produced from the adoption of the steam-shock process. The cost per extra gallon drops from $2.59 to $0.49 as the size of the oysterhouse increases from 65 to 520 GPD for those houses that do not have to purchase a boiler. The decrease in cost for purchasing the boiler is from $3.46 for the 65 GPD operation to $0.60 for the 520 GPD operation.

The remaining three columns of Tables 4 and 5 contain the new average overhead per gallon for oysterhouses with a range of existing overheads from $1.50 to $2.50/gallon of meats. These overhead figures should include all costs that will not increase with the expected increase in output. Obvious exceptions would be the cost of shell stock, oyster shucker wages, and container costs, as these will change as the output increases. An examination of these two tables will show that the adoption of the steam tunnel is a viable investment for all sizes of oysterhouses except 65 GPD and at all cost structures except for the $1.50/gallon, 130 GPD oysterhouse when a boiler must be purchased. The larger the existing house, the more attractive the investment in the steam-shock process becomes because of the economics of scale. The reduction in overhead is 11.2 percent for the $2.50/gallon, 130 GPD oysterhouse, while it is 18.4 percent for the $2.50, 520 GPD oysterhouse, when neither need to purchase a boiler. The fact that both oysterhouses start with the same overhead, yet the larger one finishes with an $0.18/gallon cost advantage, is important, because it could forecast a tendency towards larger operations if this process becomes widespread.

Table 2.—Original plant capacity, corresponding tunnel size, and capacity gains.

Original plant size (GPD)	New plant capacity (GPD)[1]	Steam-tunnel size[2]	Tunnel's full capacity (GPD)	Cost
50	65	18" × 8'	160	$5,400
100	130	18" × 8'	160	5,400
200	260	24" × 12'	321	6,600
300	390	30" × 12'	401	7,400
400	520	24" × 20'	535	8,400

[1]Assumes a 30 percent increase in output.
[2]At 5 pints/bushel and 1.5 minutes—least cost of the standard tunnel sizes (18, 24, 30 inches by 8, 12, 20 feet).

Table 3.—Tunnel costs for different sized plants.

New plant capacity (GPD)	Fuel consumption (gal/hour)	Tunnel costs fixed (per season)	Total costs (per 8-hour day)	Total costs with boiler purchase (per day)
65	2.5	$1,324	$38.82	$51.90
130	2.5	1,324	38.82	51.90
260	3.0	1,618	46.78	59.86
390	3.3	1,814	51.69	64.77
520	3.8	2,060	59.33	72.40

Table 4.—Costs per gallon of output without boiler purchase.

New plant cap. (GPD)	Costs per addl. gallon	New overhead cost per gallon when old overhead was: $1.50/gal	$2.00/gal	$2.50/gal
65	$2.59	$1.75	$2.13	$2.52
130	1.29	1.45	1.84	2.22
260	0.78	1.33	1.72	2.10
390	0.57	1.28	1.67	2.06
520	0.49	1.27	1.65	2.04

Table 5.—Costs per gallon of output with the boiler purchase.

New plant cap.	Costs per addl. gallon	New overhead cost per gallon when old overhead was: $1.50/gal	$2.00/gal	$2.50/gal
65	$3.46	$1.95	$2.34	$2.72
130	1.73	1.55	1.93	2.32
260	1.00	1.38	1.77	2.15
390	0.72	1.32	1.70	2.09
520	0.60	1.29	1.68	2.06

Sensitivity Analysis

Since most of the values used in this paper are my estimates, based on informal exchanges with the industry and its suppliers, the sensitivity of the results to changes in the assumptions and estimates is examined. Varied estimates are conveyor cost, fuel cost and consumption, and the increase in oyster shuckers' productivity. The results are presented only for oysterhouses not needing to purchase a boiler.

When the cost of the steam tunnel is increased by 50 percent (Table 6), the cost per extra gallon of production now ranges from $2.88 for the 65 GPD oysterhouse to $0.50 for the 520 GPD oysterhouse. Because these are additional or marginal production costs, the adoption of the new technology will produce a lowering of costs if they are below the old average overhead costs. If they are above the old costs, then the adoption of the technology will increase costs. The extra costs are still below $1.50/gallon for all operations of 130 GPD and larger. The 50 percent increase in the tunnel

Table 6.—Results of the sensitivity analysis.

New plant size	Marginal cost per gallon				
	Tunnel cost increased 50 percent	Fuel consumption increased 2 gallons/hour	Fuel cost $2.00/gallon	20% increase in shucker efficiency	Original assumptions
65	$2.88	$4.19	$3.25	$3.88	$2.59
130	1.44	2.09	1.63	1.94	1.29
260	0.86	1.18	0.97	1.16	0.78
390	0.64	0.91	0.72	0.86	0.57
520	0.55	0.61	0.62	0.74	0.49

cost produces an 11 percent increase in the cost per extra gallon in the 130 GPD oysterhouse, and a 10 percent increase for the largest oysterhouse.

The second estimate allowed to change is the fuel consumption. Two gallons per hour of fuel consumption were added for all sizes of tunnels. This amounts to an 80 percent increase for the 18-inch by 8-foot tunnel, and a 53 percent increase for the 24-inch by 20-foot tunnel. This increased the cost per extra gallon to $2.09 (a 62 percent increase) for the 130 GPD oysterhouse. The cost per extra gallon increased from $0.45 to $0.69 for the largest operation, a 53 percent increase. The third parameter altered is the fuel price. Using the original fuel consumption estimates and increasing the cost of fuel from $1.50/gallon to $2.00 increases the cost per extra gallon of meats from $1.29 to $1.63 for the 130 GPD oysterhouse. This is a 26 percent increase in costs. The cost per extra gallon of meats for the largest operation increases from $0.49 to $0.62, also a 26 percent increase.

The last variable altered is the increase in shucker efficiency. It was lowered from 30 to 20 percent, which is the lowest of the figures appearing in the literature (Tanchoco and Coale, 1980). This increased the marginal cost to $1.94 for the 130 GPD plant and to $0.68 for the 520 GPD oysterhouse. These are increases of 50 and 39 percent, respectively. The general results of the sensitivity analysis are that while the changes may make the steam-shock process unattractive to the low-cost 130 GPD oysterhouse, the marginal cost never rises above $1.18 for the operations over 260 GPD in size and only rises above $2.00 for the 130 GPD oysterhouse for the high fuel consumption model.

Table 7.—Total cost per gallon estimates for three shucking processes.

Process	Shellstock @ $/bu yielding 5 pints	Shucking labor	Variable costs	Fixed costs	Total
Raw	$12.80	$3.59	$0.50	$2.00	$18.89
Steam-shock	12.80	3.59	0.50	1.72	18.61
Pasteurized	16.00	3.59	0.50	2.14	22.23

The Pasteurized Product

The pasteurization of the steam-shock oyster requires the heating of the meats to a temperature of at least 140°F. This produces a second cost component, in addition to the costs of the steam tunnel, due to the loss of meat yield that occurs at the higher temperature. The meat yield as a percentage of the raw meat yield versus temperature from Goldmintz et al. (1978) is plotted in Figure 3. At 140°F the meat yield loss is about 20 percent from the raw product. The steam-shock process does not seem to produce a significant loss in meat yield (Huang, 1980). The calculations for the complete costs for the three systems—raw shuck, steam-shock (at 120°F), and pasteurization (at 140°F)—are shown in Table 7. The cost of inputs used are: 5 pints/standard bushel oysters at $8.00/bushel; shucking at $0.41/pound or $3.59/gallon; overhead at $2.00/gallon; and variable costs of $0.50/gallon. The size of the oysterhouse used for the comparison is 200 GPD, increased to 260 GPD for the steam-shock process, and 208 GPD for the pasteurized product (200 × 130 percent × 80 percent). The steam-shock process reduces the total cost per gallon to $18.61 from $18.89 for the raw shucked oysters. The pasteurized oysters cost $22.23/gallon to produce, an increase of $3.34/gallon above the raw product. This is due to the loss of meat yield.

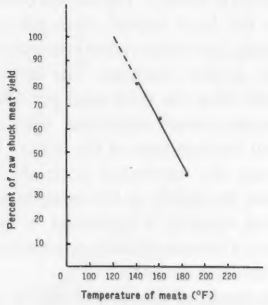

Figure 3.—Effect of temperature on meat yield (from Goldmintz et al. (1980)). Dashed part of line is linear extrapolation of Goldmintz et al. (1978) data made by Huang (1980).

There are several factors that could act to overcome the higher cost structure

produced by the loss of yield in the pasteurization process. First, the lost liquor could be added back into the pack or sold as a byproduct for other uses. Second, there is evidence (Goldmintz[2]) that the pasteurized product could have a shelf life of 6 weeks or more (at 32°F) with the use of antioxidants to prevent oxidative rancidity. This longer shelf life would produce three benefits: 1) Lower distribution costs through less frequent deliveries; 2) a longer period to build stocks for the winter holiday season's period of peak demand; and 3) a greater willingness on the part of retailers to carry larger stocks of the product, thus increasing sales through a more constant availability. Another factor could be an increase in the numbers of consumers willing (and able) to purchase the pasteurized product, because they perceived it as "safer." Sanchez (1975) found a statistically significant (F-ratio = 41.69) difference in attitudinal means with respect to "safety compared with meats" of regular and irregular users of fresh shellfish.

Conclusions

The steam-shock process of oyster shucking has the potential for decreasing costs in the oyster industry through the spreading of fixed costs over a larger production for any individual oysterhouse. The second advantage of the process is the potential of increasing the number of shuckers available through higher wages for a less-skilled job.

The pasteurization process, while appearing to be a higher cost process, has the potential for producing a differentiated product. This product could be attractive to those who do not currently eat oysters. The higher costs might be covered by a premium price, a reduction in distribution costs, and the returning of the liquor to the pack.

The usefulness of the steam-shock process for oysters from southern waters remains untested, as all of the development work has been done with mid-Atlantic stocks. I am not aware of any work that has been done to determine their gapping reactions in the steam tunnel. Another area that remains relatively unexplored is the acceptability of the process for use with highly clustered intertidal oysters. Informal contacts with members of the industry who have performed private experiments with the clustered oysters indicate that the method does not work well on these oysters. The reason is said to be that the extreme range in size and position of the individual oysters within the cluster produces an unacceptable variance in the heating. The smallest oysters are cooked by the time the larger oysters gap their shells. Because of the potential drawbacks mentioned above, more controlled experimentation should be performed in order to verify the adaptability of the steam-shock process to other oyster stocks.

[2]Goldmintz, D., Charleston Laboratory, Southeast Fisheries Center, NMFS, NOAA, P.O. Box 12607, Charleston, SC 29412. Personal commun., March 1981.

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U.S. Seafood Exports and Trade Deficit Rise

United States seafood exports in 1981 totalled a record $1.2 billion, but imports reached $4 billion, creating an approximate $3 billion fishery trade deficit, the National Oceanic and Atmospheric Administration has announced. Exports were up 15 percent from 1980. The deficit surpassed the previous high of $2.7 billion, set in 1979, the Commerce Department agency said.

Shrimp from Central and South America; groundfish fillets, blocks, and slabs from Canada; and lobsters from Australia accounted for most of the edible imports.

It was the third consecutive year when exports exceeded $1 billion. Exports have shown a steady increase from the $300 million in 1975, the year before the Magnuson Fishery Conservation and Management Act was passed. The Act gave the United States control of all fishery resources within 200 miles of its coasts and limited foreign fishing within U.S. waters.

Edible seafood valued at more than $1 billion accounted for the majority of all exports. Nonedible exports, mostly fishmeal and oil, were valued at $84 million. Japan remains this country's best customer, purchasing 48 percent of all fishery exports at a value of $560 million. Fresh and frozen salmon, at $252.6 million, was the most important export commodity. Japan, Canada, United Kingdom, France, and the Netherlands bought over 78 percent of all U.S. fishery products exported. A partial listing of U.S. fishery exports is given in Table 1.

Table 1.—Selected U.S. fishery exports for 1981 (cumulative monthly totals, January to December).

Country	Exports (t) 1980	Exports (t) 1981	Percent difference	Value ($1,000) 1980	Value ($1,000) 1981	Percent difference
Japan	108,093	138,205	Up 28%	405,876	559,968	Up 38%
Canada	55,716	53,198	Down 5%	146,865	150,577	Up 3%
Netherlands Antilles	809	699	Down 14%	3,393	2,965	Down 13%
Sweden	7,892	10,004	Up 27%	14,928	14,245	Down 5%
Norway	162	3,458	Up 2,035%	768	3,945	Up 414%
Denmark[1]	1,196	870	Down 27%	4,209	3,361	Down 20%
United Kingdom[1]	58,012	65,632	Up 13%	104,302	106,301	Up 2%
Ireland[1]	247	330	Up 34%	957	1,378	Up 44%
Netherlands[1]	44,651	39,466	Down 12%	45,803	34,696	Down 24%
Belgium and Luxemburg[1]	17,316	12,599	Down 27%	25,944	20,023	Down 23%
France[1]	14,481	14,603	No change	52,812	59,289	Up 12%
West Germany[1]	70,392	28,980	Down 59%	43,977	22,996	Down 48%
Spain[2]	5,558	1,582	Down 72%	6,650	3,111	Down 53%
Portugal	113	1,993	Up 1,664%	210	3,056	Up 1,355%
Italy[1]	9,931	1,135	Down 89%	14,381	5,419	Down 62%
Greece[1,3]	4,354	3,720	Down 15%	5,215	4,470	Down 14%
EEC totals	216,226	167,335	Down 23%	292,385	257,933	Down 12%

[1]1980 European Community (EEC) comparisons do not include Greek membership.
[2]Includes Canary Islands, a province of Spain.
[3]1981 European Community (EEC) comparisons include Greek membership (adm. 1/1/81).

U.S. Herring Exports Listed for 1981

The United States exported 80,350,643 pounds of fresh, chilled or frozen, whole or eviscerated herring in 1981 valued at $39,766,121. West Germany was the largest European purchaser importing 647,595 pounds worth $187,839, followed by France with imports of 21,383 pounds and the United Kingdom with 8,800 pounds. The majority of the herring exported was purchased by Japan, 50,631,000 pounds; Canada, 15,467,914 pounds; and Korea, 13,448,130 pounds.

The United States exported 19,865,444 pounds of fresh, chilled or frozen herring fillets, steaks, and portions worth $11,544,142 in 1981. West Germany was the largest importer with 6,622,814 pounds worth $2,195,896 while other EEC member countries, Greece, Belgium, and Luxemburg, imported 75,716 pounds valued at $33,573.

U.S. Eel Exports Noted for 1981

Total U.S. exports of fresh, chilled, or frozen eels for all of 1981 were 979,849 pounds valued at $1,389,771 with 5 EEC member countries purchasing 723,926 pounds or 74 percent of this total. West Germany imported 230,097 pounds, Belgium and Luxemburg imported 180,606 pounds, Italy imported 164,456 pounds, the Netherlands imported 147,527 pounds, and France imported 1,240 pounds.

The United States exported 42,630 pounds of live eels in December 1981 worth $68,441. Three EEC member countries purchased all but 2 percent of the live eels exported during the month: Italy imported 22,359 pounds, the Netherlands imported 11,960 pounds, and West Germany purchased 7,326 pounds. Live eel exports for all of 1981 totaled 936,917 pounds worth $1,328,478 with 6 EEC member countries purchasing 852,656 pounds or 91 percent of this total. Belgium and Luxemburg imported 320,232 pounds, Italy imported 245,364 pounds, the Netherlands imported 150,004 pounds, West Germany im-

ported 123,094 pounds, Denmark imported 11,950 pounds, and the United Kingdom imported 2,012 pounds.

The United States exported 137,321 pounds of fresh, chilled, or frozen eels (except live) in December valued at $199,694. Four EEC member countries purchased all but 3 percent of the fresh, chilled, or frozen eels exported during December: West Germany purchased 48,900 pounds, Italy imported 37,500 pounds, the Netherlands imported 29,300 pounds, and Belgium and Luxemburg purchased 17,500 pounds.

Salmonid Botulism in Rearing Facilities

Type E botulism was first recognized as a major cause of fish mortality in the United States in 1979 by Mel Eklund and his research group at the NMFS Northwest and Alaska Fisheries Center's Utilization Research Division. This outbreak caused an estimated loss of 1 million juvenile coho salmon reared in earth bottom ponds at the Washington State Elokomin Hatchery.

In the years 1979-81, botulism has been confirmed as a major cause of fish mortality in five salmon and three steelhead hatcheries in Washington and one salmon hatchery in Oregon. These outbreaks have resulted in losses of over 2 million juvenile salmon and steelhead. Earlier records indicate that botulism may have caused major fish mortality in some of these hatcheries as early as 1960.

Results from laboratory and field studies indicate that *Clostridium botulinum* type E, the bacteria causing type E botulism, grows and produces toxin in dead fish that remain on the bottom of the rearing ponds. Live fish cannibalize the decomposing fish and consume lethal levels of type E toxin. Fish with botulism die and become additional substrates for type E organisms and sources of toxin for other live fish.

During the summer of 1981, Eklund and his group worked closely with the State hatchery personnel in diagnosing the disease, helping save over 3 million fish, and preventing the employees of the hatcheries from introducing botulism to themselves or members of their families.

The practices used during the past summer to stop botulism outbreaks were to move the fish to other ponds away from the toxin source and to continually remove dead fish from the rearing ponds. In some rearing ponds, the daily removal of dead fish is often impossible because of the cloudiness and depth of the water. Further research is in progress to develop a more permanent overall solution to the botulism problems. The first publication describing these outbreaks will be published in *Aquaculture* during the first quarter of 1982.

Mel W. Eklund

Thermally Processed Products May Be a Potential Use for Alaska Pollock

Utilization of the Alaska pollock resource in the Bering Sea poses an interesting challenge for the U.S. fishing industry. Although pollock can be easily caught by U.S. fishermen and delivered in large volume, the processing sector is faced with several obstacles that must be overcome before it can economically handle and process the pollock. To develop a diversified large volume fishery for pollock, the industry needs processing alternatives for fresh, frozen, canned, cured, and fabricated products that can utilize pollock in various forms and grades.

Canning, or thermal processing, pollock may be one approach to solve some of these obstacles, according to the Utilization Research Division, NMFS Northwest and Alaska Fisheries Center, Seattle, Wash. Preliminary trials to prepare salmon-style canned products from pollock were very disappointing. Thermal processing resulted in severe shrinkage of the flesh as well as excessive cook drip and a pronounced pollock flavor and odor in the canned pollock. Precooking the pollock prior to thermal processing overcame these undesirable changes.

When the thermally processed pollock was evaluated as a fish spread by taste panelists, they found it to have a flaky texture, mild flavor and odor, and a white and pleasing appearance. From these initial trials, it appears that nutritious and highly acceptable products can be prepared from thermally processed pollock. However, experience has taught us that further work is needed to determine the effects of handling and processing on the quality changes in pollock. Further work is also needed to determine the effects of the chemical changes occurring during thermal processing on the shelf-life of the canned pollock. Economic feasibility will be an essential phase of the work by others if our technological studies demonstrate a good potential for canned pollock products.

Jerry Babbitt

Brawner Directs NMFS Southeast Region

Jack T. Brawner has been named Director of the National Marine Fisheries Service's Southeast Region, it was recently announced by William G. Gordon, Assistant Administrator for Fisheries, National Oceanic and Atmospheric Administration.

Brawner's career with NMFS (and its predecessor agency, the Bureau of Commercial Fisheries) includes various positions in management, industry and consumer marketing services, and fishery development programs. He has served as Chief of the Southeast Region's Fisheries Management Division since April 1977.

NOAA's Office of Fisheries manages and conserves the fishery resources within 200 miles of the U.S. coast; protects vital habitats, and whales, other marine mammals, and endangered species; oversees programs to assist the economic development of the U.S. fishing industry; and conducts research to support these activities.

A native of Florida, Brawner holds an A.B. and an M.A. degree in economics from Stetson University in Deland, Fla. In addition to fisheries experience in the federal sector, he has fished commercially and is an enthusiastic recreational fisherman.

Nigeria Plans Large Fishing Fleet Expansion

Development Program

Nigeria's oil exports have enabled its Government to finance Africa's most ambitious development program. Nigeria has the largest population of any country in Africa and the Government has given priority to increasing food production so that the needs of its rapidly increasing population can be met. Nigerian officials became interested in the fishing industry when the 1973-74 drought reduced cattle herds. Since then, the Government has promoted fisheries as a substitute for beef. Both agriculture and fisheries have benefited from development projects initiated by the Federal and State Governments. Much of Nigeria's fisheries development has either been Government supported or undertaken by State-owned companies. The Nigerian private sector, however, has also participated in the fishing industry.

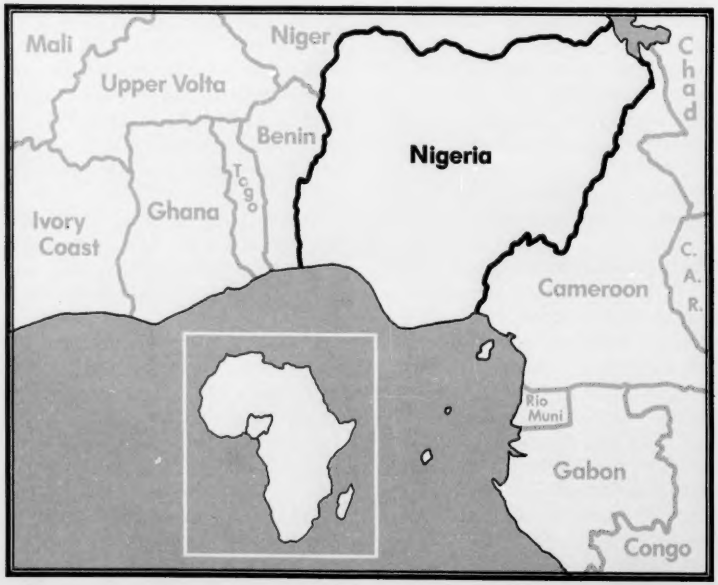
Fleet Expansion

The Government has placed a special emphasis on expanding the fishing fleet, both coastal and offshore. Because few vessels are built locally, Nigeria must import vessels from foreign shipyards. Combined government and private initiatives since 1976 have financed such purchases from eight different countries. About 100 such purchases have been documented (Table 1), but there may have been other unreported purchases. Details of fishing vessel purchases include the following:

Table 1.—Nigerian fishing vessel imports, 1976-81.

Country	Number	
	Ordered	Delivered[1]
Italy	4	–
Japan	3	–
Mexico	1	1
Norway	6	5
Poland	47	14
Spain	2	2
United Kingdom	11	4
United States	22	16
Total	96	42

[1]This category lists only reported deliveries.



Italy: Mariotti Ltd.[1] of Italy constructed four vessels for Nigeria's Imano Ltd. in 1980. All four vessels were scheduled for delivery in 1980.

Japan: A Japanese firm sold two vessels to Nigeria in 1976. In addition, the Japanese Government announced that it planned to donate a $4.7 million research vessel to the Nigerian Institute for Oceanography and Marine Research in November 1981.

Mexico: A Mexican shipyard delivered a trawler to Nigeria in May 1980.

Norway: Soviknes Verft of Norway agreed in 1979 to construct six vessels for the Nigerian National Fishing Company. The six vessels, which cost $51 million, included two factory trawlers, two motherships, and two purse seiners. These vessels will have the capacity to catch about 30,000 t of fish per year. In October 1981, five of these six vessels were delivered and are now operated by joint Nigerian-Norwegian crews. Some problems have been reported, however, and several Norwegian crewmen reportedly quit as the Nigerian company was consistently late with wage payments.

Poland: Poland's Navimor company delivered two medium-sized vessels to the Nigerian Government in 1979. An additional 45 vessels were ordered in 1980, at a per-unit cost of $124,000. Deliveries were scheduled for 1980-82; 12 of the vessels were reportedly delivered by August 1981. The Nigerian Government plans to distribute the vessels to fishery cooperatives.

Spain: A Spanish firm delivered two

[1]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

trawlers to the Nigerian company Abasubong Fisheries and Sea Products Ltd. in 1977.

United Kingdom: The United Kingdom has been one of Nigeria's most important suppliers of fishing vessels. The Cyganes company delivered a fishery research vessel in 1980. British United Trawlers of Liverpool delivered three freezer trawlers to Wale Seafoods in 1979, which are currently manned by joint Nigerian-U.K. crews. Wale Seafoods was reportedly dissatisfied with these vessels, however, when they developed engine trouble in 1980. Shetland Boats constructed a fish transport vessel for Nigeria in 1978. A British shipyard agreed to construct six fishing/recreational vessels for Nigeria at a total cost of $73,000 in 1977.

United States: Nigerian commercial relations with the U.S. have expanded markedly in recent years and this expanding trade has included fishing vessels. Marine Mart and Monica Trawlers and Fishing Equipment, both of Texas, agreed in 1981 to construct four vessels for Nigeria's West Coast Fisheries. West Coast plans to use these vessels for both shrimp and finfish. Saint Augustine Trawlers of Florida agreed in 1978 to construct a vessel for Seastate Seafoods Industry of Nigeria. Bender and Quality Marine, both of Alabama, delivered 16 shrimp vessels to the Nigerian National Shrimp Company in 1977-78. Quality Marine constructed a vessel in 1977 for training Nigerian fishing crews.

Future Plans

Nigeria plans to continue expanding its fisheries sector. The Government's Fourth National Development Plan (1981-85) alone proposed $154 million for fisheries development during the period covered by the plan. Future vessel purchases are likely, although specific information is not available. (Source: IFR-82/21.)

Netherlands Antilles Fishery Rules Listed

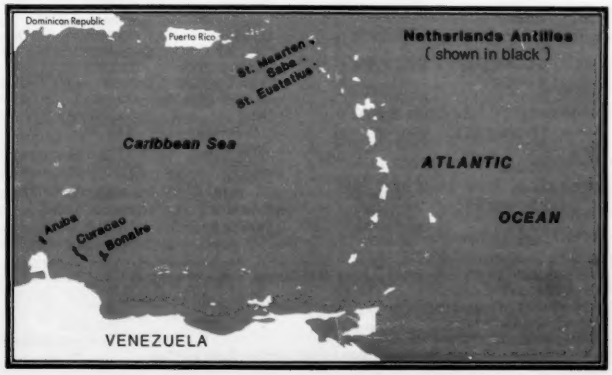
The Netherland Antilles (see map) has a 3-mile territorial sea and has not yet claimed an extended fisheries or economic zone[1]. The Antillean Central Government has requested the Dutch Government to extend this zone to 12 miles, and it is expected that this will be enacted in the near future. Even though the Netherlands has not claimed a 200-mile zone for the Antilles, it has signed a treaty with Venezuela delineating their common marine boundary. The Netherlands Antilles has delayed a 200-mile claim, since the islands border several other neighboring countries (Dominican Republic, United States, United Kingdom, and France). A 200-mile claim will necessitate separate marine boundary negotiations with each neighboring country.

The Constitution of the Netherlands Antilles (ERNA) confers responsibility to the Central Government (Eilandenregeling) over the 3-mile territorial sea (including the inner bays), while responsibility for the development of fisheries has been relegated to the individual island governments. This has resulted in some legal confusion. Neither the Central Government nor the individual islands have any fisheries legislation.

Despite the fact that there is no fisheries legislation, a foreign vessel fishing within the 3-mile territorial waters can be detained on the grounds that the Netherlands Antilles immigration laws have been violated, since the crew has been employed without a valid working permit. It is unclear, however, what sanctions can be applied in such a case, since the laws applied were not intended to deal with such matters. Although detention of the vessel will probably stand up in court, possible sanctions could probably be successfully challenged. It is also unclear whether a foreign-registered vessel could apply for working permits and fish in the waters claimed by the Netherlands Antilles. The only other Antillean Central Government regulations concerning fisheries are export limitations and a permit system for tropical seawater aquarium fish.

In additon to the Antillean Central Government's immigration laws and aquarium fish export regulations, the individual island governments have enacted legislation to conserve reef areas. These regulations, although similar, differ from island to island. Generally, they prohibit spearfishing, the use of explosives and poisons, the collection of black and stony coral, and the catch of undersized and berried lobsters. On some islands (Aruba and Bonaire), marine turtles are also protected. Some lawyers contend that all these regulations are in conflict with ERNA, and that they could be challenged in Antillean courts on constitutional grounds, primarily over the unresolved issue of the jurisdictional relationship between individual island governments and the Central Government. (Source: IFR-82/27.)

[1]Since 1954 the Netherland Antilles have been fully autonomous in internal affairs. The Central Government consists of a Governor and an elected Council of Ministers, but each of the insular communities (Aruba, Bonaire, Curacao, and the Windward Islands) has considerable local autonomy.



National Maritime Claims Listed

The Office of the Geographer of the U.S. Department of State has prepared a list of national maritime claims by 134 independent coastal countries. The report includes lists of territorial sea claims, fishing limits, and 200-mile Exclusive Economic Zones.

These national maritime claims are for general reference only. These listings do not necessarily reflect acceptance or recognition by the United States Government of these particular claims.

Users of these lists should recognize the limit of application of these data. More specific information, such as claimed baseline, negotiated or claimed boundaries with neighboring states, etc., should be obtained for precise interpretive analysis.

Table 1 lists territorial sea and fishing limit claims and the number of adherents as of 1 February 1982. At this time there are 137 independent coastal states (plus Ukrainian SSR). (Source: IFR-82/24.)

Table 1.—Territorial sea and fishing limit claims summary.

Breadth of claims (n.mi.)	Territorial sea claims (no. of states)	Fishing limit claims (no. of states)
3	24	3
4	2	–
6	4	3
12	78	29
15	1	1
20	1	–
25	–	1
30	2	–
35	1	1
50	4	3
70	1	–
100	1	–
150	1	3
200[1]	14	92
R/P[2]	3	2
N.L.[3]	1	–

[1]Boundary situations with neighboring states prevent many countries from extending their fishing or economic zones to a full 200 n.mi. Also, 56 states claim an extended economic zone.
[2]R/P = rectangular/polygonal.
[3]N.L. = no legislation.

200 n.mi. Economic Zones[1]

Bangladesh	Honduras	Oman
Barbados	Iceland	Pakistan
Burma	India	Papua New Guinea
Cape Verde	Indonesia	Philippines
Colombia	Ivory Coast	Portugal
Comoros	Kampuchea	Sao Tome & Principe
Costa Rica	Kenya	Seychelles
Cuba	Korea, North[2]	Spain
Djibouti	Madagascar[3]	Sri Lanka
Dominica	Maldives[4]	Suriname
Dominican Republic	Malaysia	Thailand
Fiji	Mauritania	Togo
France	Mauritius	United Arab Emirates
Grenada	Mexico	Vanuatu
Guatemala	Morocco	Venezuela
Guinea	Mozambique	Vietnam
Guinea-Bissau	Nauru	Yemen (Aden)
Guyana	New Zealand	
Haiti	Nigeria	
	Norway	

[1]Boundary situations with neighboring states prevent many states from extending their economic zones to a full 200 n.mi.
[2]North Korea has also claimed a 50-mile "military boundary line" in which all foreign vessels and aircraft are banned without permission.
[3]Madagascar claims a 150-n.mi. economic zone.
[4]The Maldives economic zone is defined by geographical coordinates. The zone is in part a rectangle and in part a boundary with India. The breadth of the zone varies from about 35 n.mi. to over 300 n.mi.

National Maritime Claims: Fishing Limits

3 n.mi. (3)

Bahrain
Jordan
Qatar

6 n.mi. (3)

Greece
Israel
Lebanon

12 n.mi. (29)

Algeria
Antigua & Barbuda
Belize
Bulgaria
China
Cyprus
Egypt
Equatorial Guinea
Ethiopia
Finland
Iraq
Italy
Jamaica
Kuwait
Libya
Monaco
Romania
Saint Lucia
St. Vincent and the Grenadines
Saudi Arabia
Singapore
Sudan
Trinidad & Tobago
Tunisia
Turkey
W. Samoa
Yemen (Sanaa)
Yugoslavia
Zaire

15 n.mi. (1)

Albania

25 n.mi. (1)

Malta

35 n.mi. (1)

Syria

50 n.mi. (3)

Cameroon
The Gambia
Tanzania

150 n.mi. (3)

Gabon
Madagascar
Senegal

200 n.mi.[1,2] (92)

Angola (176,600)
Argentina (339,500)
Australia (1,310,900)
The Bahamas (221,400)
Bangladesh (22,400)
Barbados (48,800)
Belgium (800)
Benin (7,900)
Brazil (924,000)
Burma (148,600)
Canada (857,000)
Cape Verde (230,200)
Chile (667,300)
Colombia (175,900)
Comoros (72,600)
Congo (7,200)
Costa Rica (75,500)
Cuba (105,800)
Denmark[3] (426,900)
Djibouti (1,800)
Dominica
Dominican Rep. (78,400)
Ecuador (338,000)
El Salvador (26,800)
Fiji (331,000)
France[4] (2,083,400)
German Dem. Rep. (2,800)
Germany, Fed. Rep. (11,900)
Ghana (63,600)
Grenada (78,000)
Guatemala (28,900)
Guinea (20,700)
Guinea-Bissau (43,900)
Guyana (38,000)
Haiti (46,800)
Honduras (58,600)
Iceland (252,800)
India (587,600)
Indonesia (1,577,300)
Iran (45,400)
Ireland (110,900)
Ivory Coast (30,500)
Japan (1,126,000)
Kampuchea (16,200)
Kenya (34,400)
Kiribati (770,000)
Korea, North (37,800)
Korea, South (101,600)
Liberia (67,000)
Malaysia (138,700)
Mauritania (45,000)
Mauritius (344,500)
Mexico (831,500)
Morocco (81,100)
Mozambique (163,900)
Nauru (125,700)
Netherlands (24,700)
New Zealand (1,409,500)
Nicaragua (46,600)
Nigeria (61,500)
Norway (590,500)
Oman (163,800)
Pakistan (92,900)
Panama (89,400)
Papua New Guinea (690,000)
Peru (229,400)
Philippines (520,700)
Poland (8,300)
Portugal (517,400)
Sao Tome & Principe (37,400)
Seychelles (393,400)
Sierra Leone (45,400)
Solomon Is. (325,400)
Somalia (228,300)
South Africa (452,900)
Soviet Union (1,309,500)
Spain (355,600)
Sri Lanka (150,900)
Suriname (29,500)
Sweden (45,300)
Thailand (25,000)
Togo (600)
Tuvalu (95,700)
(Ukrainian SSR)
United Arab Emirates (17,300)
United Kingdom[5] (520,500)
United States[6] (2,831,400)
Uruguay (34,800)
Vanuatu
Venezuela (106,100)
Vietnam (210,600)
Yemen (Aden-160,500)

R/P[7]

Maldives (279,700)
Tonga (173,800)

[1]Boundary situations with neighboring states prevent many states from extending their fishing zones to a full 200 n.mi.
[2]Numbers in parentheses represent the approximate area enclosed (n.mi.[2]).
[3]Includes Greenland and Faroe Islands.
[4]Includes all overseas departments and territories.
[5]Includes Bermuda, British Virgin Islands, the Cayman Islands, and the Turks and Caicos Islands, Pitcairn, Henderson, Ducie, Oeno Islands, St. Helene, and Ascension.
[6]Includes Puerto Rico, U.S. Virgin Islands, American Samoa, Guam, Johnson Atoll, Wake Island, Jarvis Island, Kingman Reef, Howland and Baker Islands, and the North Marianas.
[7]R/P = rectangular/polygonal claim.

National Maritime Claims: Territorial Sea

3 n.mi. (24)	4 n.mi. (2)	Equatorial Guinea	Nauru	15 n.mi. (1)	150 n.mi. (1)
Antigua & Barbuda	Finland	Ethiopia	New Zealand	Albania	Senegal
Australia	Norway	Fiji[1]	Oman		
The Bahamas		France	Pakistan	20 n.mi. (1)	200 n.mi. (14)
Bahrain	6 n.mi. (4)	Grenada	Papua New Guinea	Angola	Argentina[5]
Belgium		Guatemala	Poland		Benin
Belize	Dominican Republic	Guinea	Portugal	30 n.mi. (2)	Brazil
Chile	Greece	Guinea-Biss.	Romania		Congo
Denmark	Israel	Guyana	Sao Tome & Principe[1]	Nigeria	Ecuador
Dominica	Turkey (12 n.mi. in the Black Sea)	Haiti	Saudi Arabia	Togo	El Salvador
German Dem. Rep.		Honduras	Seychelles		Ghana
Germany, Fed. Rep.		Iceland	South Africa	35 n.mi. (1)	Liberia
Ireland	12 n.mi. (78)	India	Soviet Union		Nicaragua
Jordan		Indonesia	Spain	Syria	Panama
Kiribati	Algeria	Iran	Sri Lanka		Peru
Netherlands	Bangladesh	Iraq	Sudan	50 n.mi. (4)	Sierra Leone
Qatar	Barbados	Italy	Suriname		Somalia
Saint Lucia	Bulgaria	Ivory Coast	Sweden	Cameroon	Uruguay[5]
St. Vincent and the Grenadines	Burma	Jamaica	Thailand	The Gambia	R/P[6] (3)
Singapore	Canada	Japan[3]	Trinidad & Tobago	Madagascar	
Solomon Is.[1]	Cape Verde[1]	Kampuchea	Tunisia	Tanzania	Maldives
Tuvalu	China	Kenya	(Ukrainian SSR)	70 n.mi. (1)	Philippines[1]
United Arab Emirates[2]	Colombia	Korea, N.	Vanuatu		Tonga (12 for Minerva Reef)
United Kingdom	Comoros	Korea, S.[4]	Venezuela	Mauritania	
United States	Costa Rica	Kuwait	Vietnam		N.L.[7] (1)
	Cuba	Libya	W. Samoa	100 n.mi. (1)	
	Cyprus	Malaysia	Yemen (Aden)		
	Djibouti	Malta	Yemen (Sanaa)	Gabon	Lebanon
	Egypt	Mauritius	Yugoslavia		
		Mexico	Zaire		
		Monaco			
		Morocco			
		Mozambique			

[1]Maritime limits measured from claimed "archipelagic lines" which generally connect the outermost points of outer islands.
[2]For Sharjah, 12 n.mi.
[3]Japan's territorial sea remains at 3 n.mi. in five "international straits."
[4]South Korea's territorial sea remains at 3 n.mi. in the Korea Strait.
[5]Overflight and navigation permitted beyond 12 n.mi.
[6]R/P = rectangular/polygonal claim.
[7]N.L. = no legislation.

European Community Fisheries Aid

The European Community (EC) Commission has granted the second installment of 1981 aid from the European Agriculture Guidance and Guarantee Fund for several fishery projects in four countries. EC aid for these projects totals $3 million.

Denmark will receive $0.6 million in aid for 12 projects in the fishery sector: Modernization of 8 fish processing plants at Frederikshvn, Esbjerg, Fredericia, Hirtshals, Jutland, and at Ronne (Bornholm Island); the construction of a plant producing fillets in Lolland and a herring processing plant on Bornholm; and the modernization of a cod-liver oil processing plant at Skagen, Jutland.

Ireland will receive $1.3 million in aid for three fishery projects: Modernization of one fish processing plant, the construction of an additional plant in County Donegal, and the assistance for a third plant in County Cork.

Italy will receive $0.2 million for one fishery project: The expansion of a fish processing plant at Pietrasanta, Lucca Province.

Note: Unless otherwise credited, material in this section is from either the Foreign Fishery Information Releases (FFIR) compiled by Sunee C. Sonu, Foreign Reporting Branch, Fishery Development Division, Southwest Region, National Marine Fisheries Service, NOAA, Terminal Island, CA 90731, or the International Fishery Releases (IFR), Language Services Biweekly (LSB) reports, or Language Services News Briefs (LSNB) produced by the Office of International Fisheries Affairs, National Marine Fisheries Service, NOAA, Washington, DC 20235.

The United Kingdom will receive $0.9 million for the modernization of four fish processing plants. One of the plants is located at Fraserburg, Aberdeenshire; two at Whitehaven, Cumbria; and one at Annan, Dumfrieshire. (Source: IFR-82/30.)

Japan's 1981 Shrimp Imports Set Record

Japanese imports of frozen shrimp in 1981 were 161,725 metric tons (t), a new record surpassing by 2 percent the previous high of 158,672 t set in 1979, according to the customs clearance data released by the Finance Ministry of Japan. In contrast to the increase in quantity, the value of the imports dropped to ¥269,152 million (1,223 million at ¥220 = US$1), down 11 percent from the 1979 import value, due primarily to heavy purchases of low-priced, peeled and deveined shrimp. The import prices averaged ¥1,664/kg ($3.43/pound) for the year, a decrease of 1 percent from 1980 and 12 percent from 1979. In value, the shrimp imports represented 34 percent of the total fishery products imported by Japan in 1981.

Since Japan liberalized its shrimp imports in 1961, purchases from foreign countries rose steadily save for brief lapses in 1968, 1974, and 1980. Shrimp imports in 1981 rose more than 39-fold over 1961. Annual imports in excess of 100,000 t have been maintained since 1973. Between 1961 and 1970, Mexico and Mainland China were major suppliers of shrimp to Japan. Since 1971, however, India and Indonesia have replaced them as leading suppliers and accounted for 40 percent of Japan's total shrimp imports in 1981. Mainland China was the third and Mexico was the tenth major supplier in 1981.

Countries which supplied over 10,000 t each in 1981 were India with 40,049 t, Indonesia 24,193 t, Mainland China 14,954 t, Australia 11,522 t, and Thailand 10,321 t. Other important suppliers included Taiwan with 7,774 t, Pakistan 6,382 t, Norway 3,373 t, Hong Kong 3,270 t, and Mexico 3,137 t.

Record imports for the year were

reported from India and Mainland China. Exports from Indonesia dropped sharply during 1981, down 12 percent from 1980 and 18 percent from 1979. Imports from the United States were 123 t. (Source: FFIR 83-4).

Table 1.—Japanese frozen shrimp imports in metric tons (t) and million yen (10^6¥), by leading countries of origin, 1957-81 (excluding spiny lobster).

Country of origin	Item	Year													
		1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Korea, South	t	12	44	9	122	175	437	630	1,030	1,003	846	1,400	1,805	527	400
	10^6¥	1	5	<1	14	30	81	204	304	328	371	996	1,032	222	257
China, Mainland	t	1,470	1,842	231	206	450	1,441	2,660	5,484	5,874	11,768	5,003	3,769	4,135	6,247
	10^6¥	483	744	87	79	256	832	1,883	4,060	4,065	8,154	3,713	2,969	4,127	6,940
Mexico	t				52	2,600	827	3,501	4,663	5,209	4,889	7,994	5,768	5,511	7,209
	10^6¥				34	1,723	722	2,775	3,097	3,626	4,122	6,998	5,247	5,653	7,186
Hong Kong	t				196	303	440	2,393	1,679	2,579	3,170	3,001	3,626	4,230	3,058
	10^6¥				75	176	287	1,338	1,179	1,777	2,470	2,668	3,438	4,626	3,326
Australia	t				<1	<1	11	400	694	543	685	966	924	3,382	3,664
	10^6¥				<1	<1	9	336	512	426	616	923	936	3,668	4,054
India	t					27	15	42	641	850	993	2,146	3,164	4,863	6,336
	10^6¥					17	10	16	297	429	623	1,660	2,363	4,304	5,288
Thailand	t						40	541	1,484	1,975	3,690	5,089	4,581	6,395	5,982
	10^6¥						26	412	1,055	1,358	2,614	3,720	4,011	5,453	5,048
Vietnam	t						174	361	142	319	487	317	61	63	25
	10^6¥						103	229	85	209	346	269	69	71	24
Pakistan	t						32	129	134	205	250	1,199	1,635	2,645	2,276
	10^6¥						24	94	82	127	161	982	1,296	2,346	1,949
China, Taiwan	t							172				759	852	1,305	2,487
	10^6¥							138				737	864	986	1,697
Malaysia	t							<1	7	13	107	473	575	1,650	2,060
	10^6¥							<1	5	8	75	383	532	1,339	1,470
Philippines	t								27	19	12	57	101	98	357
	10^6¥								20	13	9	44	100	91	314
Sabah	t								196		701	984	924	1,076	993
	10^6¥								100		469	669	936	830	787
Indonesia	t											14	852	1,305	3,684
	10^6¥											13	864	986	3,167
Brazil	t											249	353	684	656
	10^6¥											238	356	604	614
Total[1]															
Metric ton		1,482	1,886	240	624	4,057	3,642	11,707	17,086	21,010	36,156	44,465	35,203	48,885	57,145
Million ¥		484	749	88	234	2,509	2,220	8,449	11,317	12,937	21,630	28,703	28,108	43,829	49,329
No. of suppliers		3	2	3	7	11	17	26	28	24	30	51	46	51	51
Average price ¥/kg		326	397	366	375	618	609	721	662	615	598	645	798	896	863

Country of origin	Item	Year										
		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Korea, South	t	566	470	2,571	3,126	2,932	4,673	2,574	2,460	2,219	2,501	2,034
	10^6¥	184	219	2,138	2,457	3,380	3,836	3,564	2,780	3,046	3,711	3,112
China, Mainland	t	5,283	3,519	4,475	9,483	9,767	5,569	3,749	9,197	12,082	14,501	14,954
	10^6¥	6,354	4,766	6,371	14,195	13,996	12,747	8,822	18,715	29,008	30,770	30,251
Mexico	t	6,520	5,406	8,838	4,580	4,085	5,235	4,184	7,854	4,727	3,398	3,137
	10^6¥	7,679	6,878	11,830	6,550	7,327	12,635	9,529	14,427	11,848	8,341	6,924
Hong Kong	t	3,951	3,539	3,052	4,051	4,139	4,627	5,993	4,607	4,365	3,684	3,270
	10^6¥	5,103	4,726	4,074	5,607	6,014	10,107	12,533	8,637	10,600	7,248	6,594
Australia	t	3,974	4,095	4,269	5,189	4,662	6,189	7,742	7,546	10,955	8,052	11,522
	10^6¥	5,189	5,920	7,343	7,880	8,145	15,129	18,550	16,406	30,742	18,266	27,198
India	t	9,703	12,811	21,902	19,897	29,941	26,901	25,083	31,580	38,752	35,249	40,049
	10^6¥	8,521	12,301	17,452	17,198	27,142	39,838	34,595	35,451	54,316	43,580	53,407
Thailand	t	7,080	7,506	9,883	6,314	8,836	9,749	7,227	8,377	9,294	8,850	10,321
	10^6¥	6,465	7,465	9,603	7,094	10,950	17,739	12,553	12,355	19,272	15,165	16,464
Vietnam	t	105	1,240	662	2,154	1,188	1,174	2,760	2,411	1,794	1,665	1,763
	10^6¥	168	1,673	754	2,710	1,361	1,738	3,766	2,604	2,370	2,083	2,267
Pakistan	t	3,203	2,606	4,231	2,304	2,951	3,892	3,889	3,675	4,179	3,574	6,382
	10^6¥	2,893	2,772	4,576	2,289	3,224	6,951	6,587	4,918	7,715	5,304	8,278
China, Taiwan	t	4,464	4,555	5,040	3,244	3,395	3,241	4,389	5,566	5,998	4,990	7,774
	10^6¥	3,569	3,647	4,407	3,711	4,224	4,449	5,747	7,331	9,679	5,882	10,802
Malaysia	t	5,169	5,840	5,190	2,618	2,391	3,877	3,392	2,826	3,131	1,716	1,567
	10^6¥	3,546	4,166	4,192	2,332	2,268	5,677	5,786	4,268	6,261	3,476	2,758
Philippines	t	1,115	1,678	2,281	1,520	1,107	2,081	2,393	2,791	3,701	2,394	2,678
	10^6¥	898	1,715	2,326	1,662	1,481	3,942	4,506	4,741	8,148	4,835	5,400
Sabah	t	1,169	4,095	4,769	5,189	1,515	2,296	2,505	2,327	2,728	2,411	2,674
	10^6¥	946	5,921	7,343	7,880	1,872	4,223	4,310	3,296	4,727	3,848	4,257
Indonesia	t	8,274	13,823	18,764	19,385	21,060	25,510	25,701	28,337	29,621	27,569	24,193
	10^6¥	7,689	14,220	20,236	23,116	27,456	45,939	45,234	42,832	56,372	49,645	43,957
Brazil	t	1,075	1,929	1,195	884	400	770	1,595	2,597	2,921	2,731	1,917
	10^6¥	1,106	2,136	1,195	1,230	590	1,639	3,443	3,543	6,825	5,357	3,839
Total[1]												
Metric ton		78,874	88,120	117,474	103,310	113,672	123,334	124,780	143,962	158,672	143,256	161,725
Million ¥		73,333	89,918	118,207	117,570	137,517	218,740	212,727	209,702	301,172	240,352	269,152
No. of suppliers		60	62	63	59	55	56	58	59	61	51	55
Average price ¥/kg		929	1,020	1,006	1,134	1,209	1,773	1,704	1,456	1,898	1,677	1,664

[1]Including other countries.

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Citations

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, the year and month and volume and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10-inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 100 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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